QK1
.R695
1895
v.29

JOURNAL

AND

PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

FOR

1895.

INCORPORATED 1881.

VOL. XXIX.

EDITED BY

THE HONORARY SECRETARIES.

THE AUTHORS OF PAPERS ARE ALONE RESPONSIBLE FOR THE STATEMENTS MADE AND THE OPINIONS EXPRESSED THEREIN.

Mo. Bot. Garden,
1896.

SYDNEY:
PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH.
LONDON:
GEORGE ROBERTSON & Co.,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.

NOTICE.

THE ROYAL SOCIETY of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society," by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty the Queen, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

NOTICE TO AUTHORS.

The Honorary Secretaries request that authors of papers (to be read before the Royal Society of New South Wales) requiring illustrations by photo-lithography, will, before preparing such drawings, make application to the Assistant Secretary for patterns of the standard sizes of diagrams &c. to suit the Society's Journal.

CORRIGENDA.

Page 114, In value of R read + instead of —
„ 116, In value of c read 2 R_m in denominator
„ 132, Note 4, read *Rodger* for Rodgers.
„ 523, Footnote for page 532, read 530.

PUBLICATIONS.

—o—

Transactions of the Philosophical Society, N.S.W., 1862-5, pp. 374, out of print.

Vol.	I.	Transactions of the Royal Society, N.S.W.,					1867, pp. 83,	,,
,,	II.	,,	,,	,,	,,	,,	1868, ,, 120,	,,
,,	III.	,,	,,	,,	,,	,,	1869, ,, 173,	,,
,,	IV.	,,	,,	,,	,,	,,	1870, ,, 106,	,,
,,	V.	,,	,,	,,	,,	,,	1871, ,, 72,	,,
,,	VI.	,,	,,	,,	,,	,,	1872, ,, 123,	,,
,,	VII.	,,	,,	,,	,,	,,	1873, ,, 182,	,,
,,	VIII.	,,	,,	,,	,,	,,	1874, ,, 116,	,,
,,	IX.	,,	,,	,,	,,	,,	1875, ,, 235,	,,
,,	X.	Journal and Proceedings			,,	,,	1876, ,, 333,	,,
,,	XI.	,,	,,	,,	,,	,,	1877, ,, 305,	,,
,,	XII.	,,	,,	,,	,,	,,	1878, ,, 324, price	10s.6d.
,,	XIII.	,,	,,	,,	,,	,,	1879, ,, 255, ,,	10s. 6d.
,,	XIV.	,,	,,	,,	,,	,,	1880, ,, 391, ,,	10s. 6d.
,,	XV.	,,	,,	,,	,,	,,	1881, ,, 440, ,,	10s. 6d.
,,	XVI.	,,	,,	,,	,,	,,	1882, ,, 327, ,,	10s. 6d.
,,	XVII.	,,	,,	,,	,,	,,	1883, ,, 324, ,,	10s. 6d.
,,	XVIII.	,,	,,	,,	,,	,,	1884, ,, 224, ,,	10s. 6d.
,,	XIX.	,,	,,	,,	,,	,,	1885, ,, 240, ,,	10s. 6d.
,,	XX.	,,	,,	,,	,,	,,	1886, ,, 396, ,,	10s. 6d.
,,	XXI.	,,	,,	,,	,,	,,	1887, ,, 296, ,,	10s. 6d.
,,	XXII.	,,	,,	,,	,,	,,	1888, ,, 390. ,,	10s. 6d.
,,	XXIII.	,,	,,	,,	,,	,,	1889, ,, 534, ,,	10s. 6d.
,,	XXIV.	,,	,,	,,	,,	,,	1890, ,, 290, ,,	10s. 6d.
,,	XXV.	,,	,,	,,	,,	,,	1891, ,, 348, ,,	10s. 6d.
,,	XXVI.	,,	,,	,,	,,	,,	1892, ,, 426, ,,	10s. 6d.
,,	XXVII.	,,	,,	,,	,,	,,	1893, ,, 530, ,,	10s. 6d.
,,	XXVIII.	,,	,,	,,	,,	,,	1894, ,, 368, ,,	10s. 6d.
,,	XXIX.	,,	,,	,,	,,	,,	1895, ,, 600, ,,	10s. 6d.

CONTENTS.

VOLUME XXIX.

	Page.
Officers for 1895-96	vii.
List of Members, &c.	ix.
Art. I.—President's Address. By R. Threlfall, M.A., Professor of Physics in the University of Sydney	1
Art. II.—A Contribution to the Chemistry of Australian Myrtaceous Kinos. By J. H. Maiden, F.L.S., and H. G. Smith	30
Art. III.—Paper on Aeronautical Work. By Lawrence Hargrave [*Nine Plates*]	40
Art. IV.—Notes on two New Mineral Substances from the Australian Broken Hill Consols Mine. By E. F. Pittman, A.R.S.M., Government Geologist, Sydney.	48
Art. V.—The Cubic Parabola as applied to the Easing of Circular Curves on Railway Lines. By C. J. Merfield. (Communicated by Mr. G. H. Knibbs). [*One Plate*]	51
Art. VI.—The History, Theory, and Determination of the Viscosity of Water by the Efflux Method. By G. H. Knibbs, Lecturer on Surveying, University of Sydney. [*One Plate*]	77
Art. VII.—On the Physiological Action of the Venom of the Australian Black Snake *(Pseudechis porphyriacus)*. By C. J. Martin, B.Sc., M.B. *Lond.*	146
Art. VIII.—Considerations on the Surviving Refugees in Austral Lands of Ancient Antarctic Life. By C. Hedley, F.L.S., Assistant in Zoology to the Australian Museum	278
Art. IX.—Icebergs in the Southern Ocean. By H. C. Russell, B.A., C.M.G., F.R.S., &c. [*One Plate*]	286
Art. X.—On some New South Wales and other Minerals, Note No. 7. By A. Liversidge, M.A., F.R.S., Professor of Chemistry in the University of Sydney	316
Art. XI.—On a Natural Deposit of Aluminium Succinate in the Timber of *Grevillea robusta*, R. Br. By J. H. Maiden, F.L.S., and Henry G. Smith	325
Art. XII.—On the Amount of Gold and Silver in Sea-Water. By A. Liversidge, M.A., F.R.S., Professor of Chemistry, University of Sydney, N. S. Wales	335
Art. XIII.—The removal of Silver and Gold from Sea-water by Muntz Metal Sheathing. By A. Liversidge, M.A., F.R.S., Professor of Chemistry, University of Sydney, N.S. Wales	350
Art. XIV.—Some Folk-Songs and Myths from Samoa. By John Fraser, LL.D.	366
Art. XV.—Contributions to a knowledge of Australian Vegetable Exudations, No. 1. By J. H. Maiden, F.L.S., and Henry G. Smith	393

PAGE.

ART. XVI.—Geological Laboratory Notes, No. 1. By Rev. J. Milne Curran 404

ART. XVII.—On the occurrence of Artesian Water in Rocks other than Cretaceous. By Edward F. Pittman, A.R.S.M., Government Geologist 408

ART. XVIII.—Note on the Origin of Malachite—Observations made in an abandoned Copper Mine. By Edgar Hall. (Communicated by Professor Liversidge) 416

ART. XIX.—A comparison of the Languages of Ponape and Hawaii. By the late Rev. E. T. Doane; with additional notes and illustrations by Sidney H. Ray, Memb. Anthrop. Inst. London 420

ART. XX.—The Tensile and Compressive Strength of Magnesium. By S. H. Barraclough, B.E., M.M.E. 453

ART. XXI.—Note on some products from the Fruit of *Pittosporum undulatum* and from the leaves of the Pepper Tree (*Schinus molle*). By R. Threlfall, M.A., Professor of Physics in the University of Sydney 456

ART. XXII.—Notes on Antarctic Rocks collected by Mr. C. E. Borchgrevink. By T. W. E. David, B.A., F.G.S., Professor of Geology; W. F. Smeeth, M.A., B.E., A.R.S.M., Lecturer in Metallurgy and Demonstrator in Geology; and J. A. Schofield, F.C.S., A.R.S.M., Demonstrator in Chemistry, University of Sydney. [*Three Plates*] 461

ART. XXIII.—Notes on the Rainfall of the Southern Riverina, 1872 to 1894. By Hugh Charles Kiddle, F.R.Met.Soc. ... 492

ART. XXIV.—The Great Meteor of May 7th, 1895. By H. C. Russell, B.A., C.M.G., F.R.S. 499

ART. XXV.—The Climate of Lord Howe Island. By H. C. Russell, B.A., C.M.G.. F.R.S... 512

ART. XXVI.—Types of Australian Weather. By Henry A. Hunt, Second Meteorological Assistant, Sydney Observatory. [*Forty Diagrams.*] 513

ART. XXVII.—Timber Bridge Construction in New South Wales. By Percy Allan, A.M.Inst C.E. ... ... I.

ART. XXVIII.—Fascine Work as carried out by the Public Works Department of New South Wales. By T. E. Burrows, L.S. (Communicated by J. W. Grimshaw, M.I.C.E.) ... ... XX.

PROCEEDINGS 552

PROCEEDINGS OF THE ENGINEERING SECTION 566

PROCEEDINGS OF THE MEDICAL SECTION 569

ADDITIONS TO THE LIBRARY 572

INDEX TO VOLUME XXIX. 596

EXCHANGES AND PRESENTATIONS MADE BY THE ROYAL SOCIETY OF NEW SOUTH WALES, 1895.

Royal Society of New South Wales.

OFFICERS FOR 1895-96.

Honorary President:

HIS EXCELLENCY THE RIGHT HON. HENRY ROBERT VISCOUNT HAMPDEN.

President:

PROF. T. W. E. DAVID, B.A., F.G.S.

Vice-Presidents:

F. B. KYNGDON.

CHARLES MOORE, F.L.S., F.Z.S.

PROF. ANDERSON STUART, M.D.

PROF. THRELFALL, M.A.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, L.S.A. *Lond.*

Hon. Secretaries:

J. H. MAIDEN, F.L.S., &c.

J. W. GRIMSHAW, M. Inst. C.E.

Members of Council:

W. CHISHOLM, M.D.

C. W. DARLEY, M. Inst. C.E.

HENRY DEANE, M.A., M. Inst. C.E.

W. M. HAMLET, F.C.S., F.I.C.

G. H. KNIBBS.

H. A. LENEHAN, F.R.A.S.

PROF. LIVERSIDGE, M.A., F.R.S.

E. F. PITTMAN, Assoc. R.S.M.

H. C. RUSSELL, B.A., C.M.G., F.R.S.

ALFRED SHEWEN, M.D.

Assistant Secretary:

W. H. WEBB.

NOTICE.

Members are particularly requested to communicate any change of address to the Hon. Secretaries, for which purpose this slip is inserted.

Correct Address.

Name.....

.....

Titles, &c.....

.....

Address.....

.....

.....

Date.....

To the

Hon. Secretaries,

The Royal Society of N.S.W.,

5 Elizabeth-street, Sydney.

LIST OF THE MEMBERS

OF THE

Royal Society of New South Wales.

P Members who have contributed papers which have been published in the Society's Transactions or Journal; papers published in the Transactions of the Philosophical Society are also included. The numerals indicate the number of such contributions.

‡ Life Members.

Elected.		
1877		Abbott, The Hon. Sir Joseph Palmer, Knt. M.L.A., Speaker of the Legislative Assembly, Castlereagh-street.
1877	P 4	Abbott, W. E., 'Abbotsford,' Wingen.
1864		Adams, P. F., 'Casula,' Liverpool.
1895		Adams, J. H. M., Athenæum Club, Castlereagh-street.
1878		Alexander, George M., Grosvenor Hotel, Church Hill.
1890	P 1	Allan, Percy, Assoc. M. Inst. C.E., Roads and Bridges Branch, Public Works Department, Sydney.
1885		Allworth, Joseph Witter, District Surveyor, East Maitland.
1881		Amos, Robert, 'Kinneil,' Elizabeth Bay.
1877		Anderson, H. C. L., M.A., 161 Macquarie-street.
1890		Anderson, William.
1878		Backhouse, Alfred P., M.A., District Court Judge, 'Melita,' Elizabeth Bay.
1877		Baker, E. A.
1894		Baker, Richard Thomas, F.L.S., Assistant Curator, Technological Museum.
1894		‡Balsille, George, Sandymount, Dunedin, New Zealand.
1895	P 2	Bancroft, T. L., M.B. *Edin.*, Deception Bay, viâ Burpengary, Brisbane, Queensland.
1895	P 1	Barraclough, S. H., B.E., M.M.E., Lecturer on Applied Physics, Technical College, p.r. 16 Toxteth Road, Glebe Point.
1876		Bassett, W. F., M.R.C.S. *Eng.*, George-street, Bathurst.
1894		Baxter, William Howe, Chief Surveyor Existing Lines Office, Railway Department, p.r. 'Hawerby,' Carrington Avenue, Strathfield.
1888		Bedford, Alfred Perceval, Manager Permanent Trustee Co. of N.S.W., 16 O'Connell-street.
1877		Belfield, Algernon H., 'Eversleigh,' Dumaresq.
1875		Belisario, John, M.D., Lyons' Terrace, Hyde Park.
1876		Benbow, Clement A., 263 Elizabeth-street.
1869	P 2	Bensusan, S. L., 14 O'Connell-street, Box 411 G.P.O.
1895		Bensusan, A. J., A.R.S.M., F.C.S., Laboratory, 12 O'Connell-st.
1878		Berney, Augustus, 74 Alberto Terrace, Darlinghurst Road.
1889		Berney, George Augustus, 74 Alberto Terrace, Darlinghurst Road.

Elected		
1883		Blaxland, Herbert, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Hospital for the Insane, Callan Park, Balmain.
1888		‡Blaxland, Walter, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Broken Hill.
1893		Blomfield, Charles E., B.C.E. *Melb.*, Water Conservation Branch, Public Works Department, Hillston.
1879		‡Bond, Albert, 131 Bell's Chambers, Pitt-street.
1895		Boultbee, James W., Superintendent of Public Watering Places and Artesian Boring, Department of Mines and Agriculture.
1891		Bowman, Archer S., C.E., The Boulevarde, Strathfield.
1893		Bowman, John, C.E.
1893		Bowman, Reginald, M.B. et Ch. M. *Edin.*, Parramatta.
1876		Brady, Andrew John, Lic. K. & Q. Coll. Phys. *Irel.*, Lic. R. Coll. Sur. *Irel.*, 3 Lyons' Terrace, Hyde Park.
1891		Brennand, Henry J. W., Bank of New South Wales, Haymarket Branch, City.
1878		‡Brooks, Joseph, F.R.G.S., F.R.A.S., 'Hope Bank,' Nelson-st., Woollahra.
1886		Brown, David, 'Kallara,' Bourke.
1876		Brown, Henry Joseph, Solicitor. Newcastle.
1893		Brownless, Anthony Colling, M.B., Ch. B. *Melb.*, 285 Elizabeth-street, Hyde Park.
1891		Bruce, John Leck, Technical College, Sydney.
1877		Bundock, W. C., 'Wyangarie, Casino.
1891	P 1	Burge, Charles Ormsby, M. Inst. C.E., Engineer-in-Charge of Railway Surveys, Fitz Johns, Alfred-st. N., North Sydney.
1890		Burne, Dr. Alfred, Dentist, 1 Lyons' Terrace, Liverpool-st.
1880		Bush, Thomas James, Engineer's Office, Australian Gas-Light Company, 163 Kent-street.
1876		Cadell, Alfred, Dalmorton.
1894		Cameron, Alex. Mackenzie, Walgett, N. S. Wales.
1889		Campbell, George S.
1891		Campbell, John Honeyford, Royal Mint, Sydney.
1879		Campbell, Rev. Joseph, M.A., F.G.S., F.C.S., St. Nicola's College, Randwick.
1891		Campbell, W. Dugald, Assoc. M. Inst. C.E., Assoc. King's Coll. *Lond.*, F.G.S., 46 Leinster-street, Paddington.
1876		Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliff Road.
1894		Carleton, Henry R., M.I.C.E., 'Alameda,' Birrell-st., Bondi.
1891		Carment, David, F.I.A. *Gt. Brit. & Irel.*, F.F.A. *Scot.*, Australian Mutual Provident Society, 87 Pitt-street.
1882		Chambers, Thomas, F.R.C.P., F.R.C.S. *Edin.*, 1 Lyons' Terrace, Hyde Park.
1879	P 1	‡Chard, J. S., Licensed Surveyor, Armidale.
1878		Chisholm, Edwin, M.R.C.S. *Eng.*, L.S.A. *Lond.*, Burradoo.
1885		Chisholm, William, M.D. *Lond.*, 139 Macquarie-street, North.
1891		Clarke, Gaius, C.E., Borough Engineer, Town Hall, Rockdale.
1888		Clubbe, C. P. B., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 195 Macquarie-street.
1876		Codrington, John Frederick, M.R.C.S. *Eng.*, L.R.C.P. *Lond.* L.R.C.P. *Edin.*, Orange.

Elected		
1893		Cohen, Algernon A., M.B., M.D. *Aberd.*, M.R.C.S. *Eng.*, 71A Darlinghurst Road.
1886		Collingwood, David, M.D. *Lond.*, F.R.C.S. *Eng.*, 'Airedale,' Summer Hill.
1878		Colquhoun. George, Crown Solicitor, 'Rossdhu,' Belmore Road, Hurstville.
1876		Colyer, J. U. C., Australian Gas-Light Co., 163 Kent-street.
1856		Comrie, James, 'Northfield,' Kurrajong Heights, viâ Richmond.
1882		Cornwell, Samuel, Australian Brewery, Bourke-st., Redfern.
1878		Cottee, W. Alfred, 2 Spring-street.
1891		Coutie, W. H., M.B., Ch. B. *Univ. Melb.*, 'Warminster,' Canterbury Road, Petersham.
1892		Cowdery, George R., Engineer for Tramways, p.r. Williamstreet, Burwood.
1859	P 1	Cox, James, M.D. *Edin.*, C.M.Z.S., F.L.S., 39 Hunter-street.
1880		Cox, The Hon. George Henry, M.L.C., Mudgee.
1886		Crago, W. H., M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 34 College-street, Hyde Park.
1869		Creed, The Hon. J. Mildred, M.L.C., M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 'Ravenscraig,' Wallis-street, Woollahra.
1870		Croudace, Thomas, Lambton.
1891	P 4	Curran, Rev. J. Milne, Lecturer in Geology, Technical College, Sydney, p.r. 557 Elizabeth-street, City.
1875		Dangar, Fred. H., c/o Messrs. Dangar, Gedye, & Co., Mercantile Bank Chambers, Margaret-street.
1890		Dare, Henry Harvey, M.E., Assoc. M. Inst. C.E., Roads and Bridges Branch, Public Works Department.
1876	P 1	Darley, Cecil West, M. Inst. C.E., Engineer-in-Chief, Public Works Department.
1877		Darley, The Hon. Sir Frederick, Knt., B.A., Chief Justice, Supreme Court.
1886	P 8	David, T. W. Edgeworth, B.A., F.G.S., Professor of Geology and Physical Geography, Sydney University, Glebe. *President.*
1892		Davis, Joseph, M. Inst. C.E., Supervising Engineer, Sewerage Branch, Department of Public Works.
1878		Dean, Alexander, J.P., 54 Castlereagh-street, Box 409 G.P.O.
1885		Deane, Henry, M.A., M. Inst. C.E., Engineer-in-Chief for Railways, Railway Construction Branch, Public Works Department p.r. 'Blanerne,' Wybalena Road, Hunter's Hill.
1877		Deck, John Feild, M.D. *Univ. St. And.*, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, Ashfield.
1875		De Salis, The Hon. Leopold Fane, M.L.C., 'Tharwa,' Queanbeyan.
1894		Dick, James Adam, M.D., C.M. *Edin.*, 'Catfoss,' Belmore-road, Randwick.
1875	P 12	Dixon, W. A., F.C.S., F.I.C., Fellow and Member Institute of Chemistry of Great Britain and Ireland, Lecturer on Chemistry, The Technical College Laboratory, Sydney.

Elected		
1880		Dixson, Thomas, M.B. *Edin.*, Mast. Surg. *Edin.*, 287 Elizabeth-street, Hyde Park.
1879		Docker, Wilfred L., 'Nyrambla,' Darlinghurst Road.
1876		Docker, Ernest B., M.A. *Syd.*, District Court Judge, 'Carhullen,' Granville.
1873		Du Faur, E., F.R.G.S., Exchange Buildings, Pitt-street.
1891	P 1	Dunstan, Benjamin, F.G.S., Technical College, Sydney.
1892		Dymond, Edmund R., Assoc. M. Inst. C.E., Assoc. Inst. Elect. Eng. of Gt. Brit., King's College, Parramatta.
1890		Eddy, E. M. G., Assoc. Inst. C.E., Chief Commissioner of Railways, 'Colebrook,' Double Bay.
1894		Edgell, Robert Gordon, Roads, Bridges, and Sewerage Branch, Public Works Department.
1874		Eichler, Charles F., M.D. *Heidelberg*, M.R.C.S. *Eng.*, 56 Bridge-street.
1876		Eldred, W. H., Consul General for Chili, 'Flinton,' 186 Glebe Road.
1879	P 3	Etheridge, Robert junr., Curator, Australian Museum.
1876		Evans, George, 'Glen Ayre,' Glenmore Road, Paddington.
1881		Evans, Thomas, M.R.C.S. *Eng.*, 211 Macquarie-street, North.
1892		Everett, W. Frank, Roads and Bridges Office, Muswellbrook.
1877		‡Fairfax, Edward Ross, *S. M. Herald* Office, Hunter-street.
1868		Fairfax, James R., *S.M. Herald* Office, Hunter-street.
1887		Faithfull, R. L., M.D. *New York* (Coll. Phys. & Surg.) L.R.C.P., L.S.A. *Lond.*, 5 Lyons' Terrace.
1889		Farr, Joshua J., J.P., 'Cora Lynn,' Addison Rd., Marrickville.
1881		Fiaschi, Thos., M.D., M. Ch. Univ. *Pisa*, 39 Phillip-street.
1891		Firth, Thomas Rhodes, Principal Assistant Engineer, Railway Construction Department, Sydney; p.r. 'Glenevin,' Arncliffe.
1891		Fitzgerald, Robert D., C.E., Roads and Bridges Branch, Department of Public Works, Sydney.
1888		Fitzhardinge, Grantly Hyde, M.A. *Syd.*, District Court Judge, 'Nunda,' Birchgrove, Balmain.
1894		Fitz Nead, A. Churchill, Roads and Bridges Branch, Public Works Department, p.r. 'Thaluya,' Carlton, N.S.W.
1892		Flint, Charles Alfred, M.A., King's School, Parramatta.
1879		‡Foreman, Joseph, M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 215 Macquarie-street.
1881		Foster, The Hon. Mr. Justice (W. J.) Q.C., Enmore Road, Newtown.
1883	P 5	Fraser, John, B.A., LL.D., *Edin.*, Délégué Général (pour l'Océanie), Alliance Scientifique de Paris; Associate of the Victorian (Philosophical) Institute of Great Britain; Randwick.

Elected		
1890		Freehill, Francis B., M.A. *Syd.*, Solicitor, 'Carmena,' Wyalong-street, Burwood.
1881		Furber, T. F., Surveyor General's Office, 218 Victoria-street.
1889		Gale, Walter Frederick, F.R.A.S., Mem. A.S.P. & B.A.A., Savings' Bank of N. S. Wales, Barrack-street.
1868	P 1	Garran, Andrew, M.A., LL.D. *Syd*, Barncleuth Square, Elizabeth Bay Road.
1883		Garrett, Henry Edward, M.R.C.S. *Eng.*, c/o Messrs. Sly and Russell, Solicitors, George-street.
1877		Garvan, J. P., M.L.A., 21 Castlereagh-street.
1878		Gedye, Charles Townsend, c/o Messrs. Dangar, Gedye & Co., Mercantile Bank Chambers, Margaret-street.
1876		George, W. R., 318 George-street.
1879		Gerard, Francis, c/o Messrs. Du Faur & Gerard, Box 690 G.P.O.
1884		Gill, Rev. William Wyatt, B.A. *Lond.*, LL.D. *St. Andrews*, 'Persica,' Illawarra Road, Marrickville.
1891		Gill. Robert J., Resident Engineer, Roads and Bridges, Blayney.
1875		Gilliat, Henry A., Australian Club, Sydney.
1876	P 4	Gipps, F. B., C.E., 'Hughenden,' Cheltenham Road, Burwood.
1883		Goode, W. H., M.A., M.D., Ch.M, Diplomate in State Medicine *Dub.*; Surgeon Royal Navy; Corres. Mem. Royal Dublin Society; Mem. Brit. Med. Assoc.; Lecturer on Medical Jurisprudence, University of Sydney, 159 Macquarie-st.
1859		Goodlet, John H., 'Canterbury House,' Ashfield.
1887		Gordon, Charles Edward, 'Earlston,' East Crescent-street, North Sydney.
1886		Graham, James, M.A., M.D., M.B., C.M. *Edin.*, M.L.A., 4 Hyde Park Terrace, Liverpool-street.
1877		Griffiths, G. Neville, 369 George-street.
1891		Grimshaw, James Walter, M. Inst.C.E., M.I.Mech.E., &c., Australian Club, Sydney. *Hon. Secretary.*
1892		Gundlach, Louis Richard, A.M.I.C.E., Whistler-street, Manly.
1877		Gurney, T. T., M.A. *Cantab.*, Professor of Mathematics, Sydney University, 149 Macquarie-street.
1891		Guthrie, Frederick B., F.C.S., Department of Agriculture, Sydney.
1886		Halligan, Gerald H., C.E., 'Riversleigh,' Hunter's Hill.
1892		Halloran, Henry Ferdinand, L.S., 28 Castlereagh-street.
1887	P 5	Hamlet, William M., F.C.S., F.I.C., Member of the Society of Public Analysts; Government Analyst, Government Laboratory, Treasury Buildings.
1882		Hankins, George Thomas, M.R.C.S. *Eng.*, 'St. Ronans,' Allison Road, Randwick.

Elected		
1891		Hanly, Charles, L.S., Resident Engineer, Roads and Bridges Office, Crookwell.
1890		Harris, Rev. Edward, M.A. *Oxon.* and *Syd.*, D.D. *Oxon.*
1881		‡Harris, John, 'Bulwarra,' Jones-street, Ultimo.
1877	P 13	‡Hargrave, Lawrence, J.P., Stanwell Park, Otford.
1884		Haswell, William Aitcheson, M.A., D. Sc., F.L.S., Professor of Zoology and Comparative Anatomy, University, Sydney.
1890		Haycroft, James Isaac, M.E. Queen's Univ. *Irel.*, Assoc. M. Inst. C.E., L.S., 'Fontenoy,' Ocean-street, Woollahra.
1876		Heaton, J. Henniker, M.P., St. Stephen's Club, Westminster, London.
1891	P 1	Hedley, Charles, F.L.S., Assistant in Zoology, Australian Museum, Sydney.
1893		Henderson, John, C.E.
1890		Henry, Arthur Geddes, M.B., Ch. M. *Syd.*, Resident Medical Officer, Callan Park Asylum, Balmain.
1884		Henson, Joshua B., C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1891		Hickson, Robert, M. Inst. C.E., Under Secretary, Public Works Department, p.r. 'The Pines,' Bondi.
1876	P 2	Hirst, George D., 377 George-street.
1891		Hood, Alexander Jarvie, M.B., Mast. Surg. *Glas.*, 219 Macquarie-street, City.
1892		Hodgson, Charles George, 157 Macquarie-street.
1886		Holmes, Spencer Harrison, 'The Wilderness,' Allandale. Hunter River.
1891		Houghton, Thos. Harry, A.M.I.C.E., M.I.M.E., 12 Spring-street.
1879		Houison, Andrew, B.A., M.B., C.M. *Edin.*, 47 Phillip-street.
1891	P 1	How, William F., M. Inst. C.E., M. I. Mech. E., Wh. Sc., Mutual Life Buildings, George-street.
1877		Hume, J. K., 'Beulah,' Campbelltown.
1894	P 2	Hunt, Henry A., Second Meteorological Assistant, Sydney Observatory.
1882		Hurst, George, M.A. *Syd.*, M.B. Univ. *Lond.*, M.B., C.M. Univ. *Edin.*, Bathurst.
1886		Hutchinson, W. A., Bond-street, p.r. 'Alston,' Glebe Point.
1891		Hutchinson, William, M. Inst. C.E., Supervising Engineer, Railway Construction Branch, Public Works Department.
1895		Jacob, Albert Francis, A.M.I.C.E., 8 The Terrace, Shepherd's Hill, Newcastle.
1891		Jamieson, Sydney, B.A., M.B., M.R.C.S., L.R.C.P., 157 Liverpool-street, Hyde Park.
1884		Jenkins, Edward Johnstone, M.A., M.D. *Oxon.*, M.R.C.P., M.R.C.S. L.S.A. *Lond.*, 213 Macquarie-street, North.
1879		Johnson, James W., Norwich Chambers, Hunter-street.
1887		Jones, George Mander, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 'Viwa,' Burlington Road, Homebush.
1874		Jones, James, 'Miltonia,' Randwick.
1879		Jones, John Trevor, C.E., 'Tremayne,' North Shore.
1884		Jones, Llewellyn Charles Russell, M.L.A., Solicitor, 130 Pitt-st.

Elected		
1867		Jones, P. Sydney, M.D. *Lond.*, F.R.C.S. *Eng.*, 16 College-street, Hyde Park, p.r. 'Llandilo,' Boulevard, Strathfield.
1876		Jones, Richard Theophilus, M.D. *Syd.*, L.R.C.P. *Edin.*, 'Caer Idris,' Ashfield.
1891		Jones, Robert E., M. Inst. C.E., Roads Department, Muswellbrook
1875	P 2	Josephson, J. Percy, Assoc. M. Inst. C.E., 'Moppity,' George-st., Dulwich Hill.
1878		Joubert, Numa, Hunter's Hill.
1883		Kater, The Hon. H. E., M.L.C., 'Cheverells,' Elizabeth Bay Rd.
1873		Keele, Thomas William, M. Inst. C.E., District Engineer, Harbours and Rivers Department, Ballina, Richmond River.
1877		Keep, John, Brought on Hall, Leichhardt.
1884		Kendall, Theodore M., B.A., L.R.C.P., L.R.C.S. *Lond.*, L.M., 28 College-street, Hyde Park.
1894		Kelly, Walter MacDonnell, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S. *Glas.*, 265 Elizabeth-street.
1887		Kent, Harry C., Bell's Chambers, 129 Pitt-street.
1892	P 2	Kiddle, Hugh Charles, F. R. Met. Soc., Public School, Seven Oaks, Smithtown, Macleay River.
1891		King, Christopher Watkins, A.M.I.C.E., L.S., Roads and Bridges Branch, Public Works Department, Sydney.
1874		King, The Hon. Philip G., M.L.C., 'Banksia,' William-street, Double Bay.
1892		Kirkaldie, David, Chief Traffic Manager, New South Wales Government Railways, Sydney.
1878		Knaggs, Samuel T., M.D. *Aberdeen*, F.R.C.S. *Ird.*, 16 College-street, Hyde Park.
1881	P 3	Knibbs, G. H., F.R.A.S., L.S., Lecturer in Surveying, University of Sydney, p.r. 'Avoca House,' Denison Road, Petersham.
1877		Knox, Edward W., J.P., 'Fiona,' Bellevue Hill, Double Bay.
1875		Knox, The Hon. Edward, M.L.C., O'Connell-street.
1877		Kopsch, G., 'Saxonia,' Boulevard, Petersham.
1878		Kyngdon, F. B., F.R.M.S. *Lond.*, Deanery Cottage, Bowral. *Vice-President.*
1874		Lenehan, Henry Alfred, F.R.A.S., Sydney Observatory.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1872	P 45	Liversidge, Archibald, M.A. *Cantab.*, F.R.S.; Assoc. Roy. Sch. Mines *Lond.*; F.C.S., F.G.S., F.R.G.S.; Fel. Inst. Chemistry of Gt. Brit. and Irel.; Hon. Fel. Roy. Historical Soc. *Lond.*; Mem. Phy. Soc. *Lond.*; Mineralogical Society, *Lond.*; Edin. Geol. Soc.; Mineralogical Society, *France*; Cor. Mem. Edin. Geol. Soc.; Roy. Soc. *Tas.*; Roy. Soc. *Queensland*; Senckenberg Institute, *Frankfurt*; Soc. d' Acclimat. *Mauritius*; Hon. Mem. Roy. Soc. *Vict.*; N. Z. Institute; K. Leop. Carol. Acad. *Halle a s*; Professor of Chemistry in the University of Sydney, The University, Glebe; p.r. 'The Octagon,' St. Mark's Road, Darling Point.

Elected		
1881		Lloyd, Lancelot T., 'Eurotah,' William-street East.
1874		Lloyd, The Hon. George Alfred, M.L.C , F.R.G.S., 'Scottforth,' Elizabeth Bay.
1890	P 2	Loir, Adrien.
1887		Long, Alfred Parry, Land Titles' Office, Elizabeth-street.
1878		Low, Hamilton, H. M. Customs, Sydney.
1887		MacAllister, John F., M.B., B.S. *Melb.*, 'Ewhurst,' Stanmore Road, Stanmore.
1892		MacCarthy, Charles W., M.D., F.R.C.S. *Irel.*, 223 Elizabeth-street, Hyde Park.
1884		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 125 Macquarie-street North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.
1874		M'Cutcheon, John Warner, Assayer to the Sydney Branch of the Royal Mint.
1892		McDonagh, John M., B.A., M.D , M.R.C.P. *Lond.*, F.R.C.S. *Irel.*, 173 Macquarie-street North.
1878		MacDonald, Ebenezer, 'Kamilaroi,' Darling Point.
1886		MacDonald, John A., M. Inst. C.E., M. Inst. M.E., M. Am. Soc. C.E.
1868		MacDonnell, William J., F.R.A.S., c/o Mr. W. C. Goddard, Norwich Chambers. Hunter-street.
1877		MacDonnell, Samuel, Cape's Chambers, 3 Bond-street.
1891		McDouall, Herbert Crichton, M R.C.S. *Eng.*, L.R.C.P. *Lond.*, Hospital for Insane, Gladesville.
1876		McKay, Charles, M.D. Univ. *St. Andrews*, L.R.C.S. *Edin.*, Rooty Hill.
1891		McKay, Robert Thomas, L.S.
1893		McKay, William J. Stewart, B.Sc., M.B., Ch.M., 'Glengower,' Fraser-street, Petersham.
1876		Mackellar, The Hon. Charles Kinnard, M.L C., M.B., C.M. *Glas.*, 183 Liverpool-street, Hyde Park.
1872		Mackenzie, John, F.G S., Athenæum Club, Sydney.
1876		Mackenzie, Rev. P. F., The Manse, Johnston-st., Annandale.
1880	P 4	M'Kinney, Hugh Giffin, M.E. Roy. Univ. *Irel.*, M. Inst. C.E., Chief Engineer for Water Conservation, Athenæum Club, Castlereagh-street.
1876		MacLaurin, The Hon Henry Norman, M.L.C., M.A., M,D. *Edin.*, L.R C.S. *Edin.*, LL.D. Univ. *St. Andrews*, 155 Macquarie-st.
1894		McMillan, William, M.L.A. 'St.Albans,' Allison-st., Randwick.
1882	P 1	Madsen, Hans. F., 'Hesselmed House,' Queen-st., Newtown.
1883	P 5	Maiden, Joseph H., F.L.S., F.C.S., Corr. Memb. Pharm. Soc. Great Britain, and of Roy. Soc., S.A.; Hon. Memb. Phila. Coll. of Pharm. and Royal Netherlands Soc., (Haarlem); Superintendent of Technical Education, Sydney. *Hon. Secretary.*
1878		Maitland, Duncan Mearns, Department of Lands, Sydney.
1873		Makin, G. E., Market Square, Berrima.
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1877		Mann, John F., 'Kerepunu,' Neutral Bay.
1876		Manning, Frederic Norton, M.D. Univ. *St. And.*, M.R.C.S. *Eng.*, L S.A. *Lond.*, Hunter's Hill.

Elected		
1869		Mansfield, G. Allen, Martin Chambers, Moore-street.
1880		Marano, G. V., M.D. Univ. *Naples*, Clarendon Terrace, Elizabeth-street.
1893	P 3	Martin, Charles J., B.Sc., M.B. *Lond.*, M.R.C.S. *Eng.*, Demonstrator of Physiology. Sydney University, p.r. 225 Macquarie-st.
1879		Matthews, Robert Chr., Sheridan-street, Gundagai.
1875	P 3	Mathews, R. H., J.P., L.S., 'Carcuron,' Parramatta.
1888		Megginson, A. M., M.B., C.M. *Edin.*, 147 Elizabeth-street.
1893		Millard, Reginald Jeffery, M.B., Ch.M. *Syd.*, Hospital for Insane Callan Park, Balmain..
1887		Miles, George E., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, Hospital for Insane, Newcastle.
1873		Milford, F., M.D. *Heidelberg*, M.R.C.S. *Eng.*, 3 Clarendon Terrace, 295 Elizabeth-street.
1882		Milson, James, 'Elamang,' North Shore.
1889	P 3	Mingaye, John C. H., F.C.S., M.A.I.M.E., Assayer and Analyst to the Department of Mines, Sydney.
1892		Mollison, James Smith, M.I.C.E., Roads, Bridges and Sewerage Branch, Department of Public Works, Sydney.
1856	P 7	Moore, Charles, F.L.S., Director of the Botanic Gardens, Sydney. *Vice-President.*
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1875		Moir, James, 58 Margaret-street.
1893		Money, Angel, M.D., F.R.C.P. *Lond.*, 75 Hunter-street.
1877	P 1	Morris, William, Fel. Fac. Phys. and Surg. *Glas.*, F.R.M.S. *Lond.*, 5 Bligh-street.
1882		Moss, Sydney, 'Kaloola,' Kirribilli Point, North Shore.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd.*, 'Killountan,' Challis Avenue, Pott's Point.
1888		Mullins, George Lane, M.A.. M.D. Trin. Coll. *Dub.*, M.D. *Syd.*, F.R.M.S. *Lond.*, 'Murong,' Albion-street, Waverley.
1887		Munro, William John, M.B., C.M. *Edin.*, M.R.C.S. *Eng.*, 112 Glebe Road, Glebe.
1876		Myles, Charles Henry, 'Dingadee,' Burwood.
1893		Nangle, James, Architect, Australia-street, Newtown.
1890		Neill, Leopold Edward Flood, M.B., Ch.M. Univ. *Syd.*, No. 3 Bayswater Houses, Double Bay.
1895		Nicholls, William Hawkins, Roads Office, Muswellbrook.
1891		Noble, Ewald George, 60 Louisa Road, Longnose Point, Balmain.
1873		Norton, The Hon. James, M.L.C., LL.D., Solicitor, 2 O'Connell-street, p.r. 'Ecclesbourne,' Double Bay.
1893		Noyes, Edward, C.E., 'Waima,' Wentworth Road, Point Piper, Sydney.
1878		Ogilvy, James L., Melbourne Club, Melbourne.
1888		O'Neill, G. Lamb, M.B., C.M. *Edin.*, 291 Elizabeth-street.
1883		Oram, Arthur Murray, M.D. Univ. *Edin.*, 213 Macquarie-st., North.

Elected		
1875		O'Reilly, W. W. J., M.D., M. Ch. Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 197 Liverpool-street.
1883		Osborne, Ben. M., J.P., 'Hopewood,' Bowral.
1891		Osborn, A. F., Assoc. M. Inst. C.E., Roads and Bridges Office, Cowra.
1893		Owen, Lieut. Percy Thomas, Assistant Engineer, Military Works, Australian Club.
1875		Palmer, J. H., 'Hinton,' Queen-street, Burwood.
1880		Palmer, Joseph, 133 Pitt-st., p.r. Kenneth-st., Willoughby.
1885		Park, Archibald John, Chairman Local Land Board, Grafton.
1891		Parkinson, Henry W., Railway Department, Brisbane.
1878		Paterson, Alexander, M.D., M.A. *Edin.*, 146 Crystal-street, Petersham.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1877		Pedley, Perceval R., 227 Macquarie-street.
1877		Perkins, Henry A., 'Barangah,' Coventry Road, Homebush.
1881		Philip, Alex., L.K.Q.C.P. *Irel.*, L.R.C.S. *Irel.*, 574 Crown-street, Surry Hills.
1876		Pickburn, Thomas, M.D., C.M. *Aberdeen*, M.R.C.S. *Eng.*, 22 College-street.
1879	P 4	Pittman, Edward F., As-oc. R.S.M., L.S., Government Geologist Department of Mines, 39 Pitt-street.
1881		Poate, Frederick, District Surveyor, Tamworth.
1890		Pockley, Francis Antill, M.B., M.C. Univ. *Edin.*, M.R.C.S. *Eng.*, 227 Macquarie-street.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887		Pollock, James Arthur, B.E. Roy. Univ. *Irel.*, B.Sc. *Syd.*, Demonstrator in Physics, Sydney University.
1891		Poole, William Jr., Water Conservation Branch, Department of Public Works, Bourke.
1882	P 4	Porter, Donald, Tamworth.
1891		Pringle, Adam Thompson, Government Inspector of Vineyards, 'Alma Villa,' Parramatta Road, Concord.
1893		Purser, Cecil, B.A., M.B., Ch. M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1876		Quaife, Frederick H., M.A., M.D., Master of Surgery *Glas.*, 'Hughenden,' 19 Queen-street, Woollahra.
1865	P 1	‡Ramsay, Edward P., LL.D. Univ. St. And. *Aberdeen*, F.R.S.E., F.L.S., c/o Australian Museum, College-street.
1868		Reading, E., Mem. Odont Soc. *Lond.*, Elizabeth-street, Hyde Park, p.r. Fullerton-street, Woollahra.
1888		Reading, Richard Fairfax, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, L.D.S. *Eng.*, 151 Macquarie-street.
1881	P 3	Rennie, Edward H., M.A. *Syd.*, D.Sc. *Lond.*, Professor of Chemistry, University, Adelaide.

Elected		
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 16 College-street, Hyde Park.
1870		Renwick, The Hon. Sir Arthur, M.L.C., B.A. *Syd.*, M.D. F.R.C.S. *Edin.*, 295 Elizabeth-street.
1868	P 4	Roberts, Sir Alfred, M.R.C.S. *Eng.*, Hon. Mem. Zool. and Bot. Soc. *Vienna*, 125 Macquarie-street North.
1893	P 1	Roberts, W. S. de Lisle, C.E., Sewerage Branch, Public Works Department, Phillip-street.
1885		Rolleston, John C., C.E., Harbours and Rivers Branch, Dept. of Public Works.
1892		Rossbach, William, Assoc. M. Inst. C.E., Chief Draftsman, Harbours and Rivers Branch, Public Works Department.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, Hospital for the Insane, 'Kenmore,' near Goulburn.
1895		Ross, Colin John, B.Sc., B.E., Assoc. M. Inst. C.E., Borough Engineer, Town Hall, North Sydney.
1895		Ross, Herbert E., Consulting Mining Engineer, 121 Pitt-st.
1865		Ross, J. Grafton, O'Connell-street.
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-st., and Union Club.
1894		Rowney, George Henry, A.M.I.C.E., Water and Sewerage Board, Pitt-street, p.r. 12 Kellet-street, Darlinghurst.
1864	P 57	Russell, Henry C., B.A. *Syd.*, C.M.G., F.R.S., F.R.A.S., F.R. M.t. Soc., Hon. Memb. Roy. Soc., South Australia, Government Astronomer, Sydney Observatory.
1883		Rygate, Phillip W., M.A., B.E. *Syd.*, 14 O'Connell-street.
1875		Sahl, Carl L., German Consulate, 42 Pitt-street.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., Sydney University, Glebe.
1856	P 1	‡Scott, Rev. William, M.A. *Cantab.*, Kurrajong Heights.
1886		Scott, Walter, M.A. *Oxon.*, Professor of Greek, University, Sydney.
1891		Seaver, Thomas Whitehurch, B.C.E. Roy. Univ. *Ired.*, Water Conservation Branch, Public Works Department, p.r. Undercliffe-street, North Shore.
1877		Selfe, Norman, M. Inst. C.E., M. Inst. M.E., Victoria Chambers, 279 George-street.
1890	P 1	Sellors, R. P., B.A. *Syd.*, F.R.A.S., Sydney Observatory.
1891		Selman, D. Codrington, Wh. Sc., St. James' Chambers, King-street, City.
1891		Shaw, Percy William, C.E., 'Seswell,' Torrington Road, Strathfield.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Divisional Engineer, Railway Department, Goulburn.
1870		Shepard, A. D., Box 728 G.P.O. Sydney.
1875		Sheppard, Rev. G., B.A. *Syd.*, Berrima.
1882		Shewen, Alfred, M.D. Univ. *Lond.*, M.R.C.S. *Eng.*, 6 Lyons' Terrace, Hyde Park.
1894		Simpson, Benjamin Crispin, M. Inst. C.E., 113 Phillip-street.
1882		Sinclair, Eric, M.D., C.M. Univ. *Glas.*, Hospital for the Insane, Gladesville.

Elected		
1893		Sinclair, Russell, M.I.M.E. &c., Consulting Engineer, 97 Pitt-street.
1884		Skirving, Robert Scot, M.B., C.M. *Edin.*, Elizabeth-street, Hyde Park.
1877		Sloper, Frederick Evans, 94 Oxford-street, Paddington.
1891	P 1	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1893	P 3	Smeeth, William Frederick, M.A., B.E., F.G.S., A.R.S.M., Demonstrator in Geology, Sydney University.
1893	P 7	**Smith, Henry G., F. C. S., Mineralogist, Technological Museum, Sydney.**
1874	P 1	‡Smith, John McGarvie, Denison-street, Woollahra.
1875		Smith, Robert, M.A. *Sydney*, Marlborough Chambers, 2 O'Connell-street.
1886		Smith, Walter Alexander, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Public Works Department, N. Sydney.
1892		**Speak, Savannah J., Assoc. R.S.M.**
1893		Spencer, Thomas William Loraine, Resident Engineer, **Roads and Bridges, Armidale.**
1879		**Spry, James Monsell, Union Club.**
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., 'Fenella,' **Frederick-street, Rockdale.**
1892		Statham, Hugh Worthington, Roads Office, Blayney.
1882		Steel, John, L.R.C.P., L.R.C.S. *Edin.*, Ch. M. B.S. Univ. *Melb.*, 3 Lyons' Terrace, Hyde Park.
1889		Stephen, Arthur Winbourn, L.S., Mulgoa.
1879		‡Stephen, The Hon. Septimus A., M.L.C., 12—14 O'Connell-st.
1891		Stilwell, A. W., A.M.I C.E., 'Strathroy,' East Orange.
1892		Stuart, Charles McDonnell, B.E. Queen's Univ. *Irel.*, M. Inst. C.E. **'Dunsevirick,' Pymble.**
1883	P 2	Stuart, T. P. Anderson, M.D. Univ *Edin.*, Professor of Physiology, University of Sydney. *Vice-President.*
1892		Sturt, Clifton, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S. *Glas.*,' Wistaria,' Bulli.
1883		Styles, George Mildinhall, Commercial Bank, George-street.
1887		Sulman, John, F.R.I.B.A., 339 George-street.
1876	P 1	Suttor, The Hon. W. H., M.L.C., 264 Norwood Villa, Ocean-**street, Paddington.**
1893		‡Taylor, James, B.Sc., A.R.S.M., Government Metallurgist, Adderton Road, Dundas.
1862	P 19	Tebbutt, John, F.R.A.S., Private Observatory, The Peninsula, Windsor, New South Wales.
1878		Thomas, F. J., Hunter River N.S.N. Co., Sussex-street.
1879		Thomson, Dugald, M.L.A., c o Messrs. Thomson Bros., 9 Castlereagh-street.
1875		Thompson, Joseph, 159 Brougham-street, Woolloomooloo.
1877		Thompson, Thomas James, Eldon Chambers, 92 Pitt-street.
1885	P 2	Thompson, John Ashburton, M.D. *Brux.*, Health Department, 127 Macquarie-street.
1892		Thow, William, Locomotive Department, Eveleigh.

Elected		
1886	P 4	Threlfall, Richard, M.A. *Cantab.*, Professor of Physics, University of Sydney. *Vice-President.*
1888		Thring, Edward T., F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.
1876		Tibbits, Walter Hugh, M.R.C.S. *Eng.*, Gunning.
1894		Tidswell, Frank, M.B., M.Ch., Coogee.
1876		Toohey, The Hon. J. T., M.L.C., 'Moira,' Burwood.
1891		Tooth, Alfred Erasmus, Union Chambers, 68½ Pitt-street.
1894		Tooth, Arthur W., Australian Club, Bent-street.
1893		Townsend, George W., C.E.
1882		Traill, Mark W., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Coolabah,' Belmore-street, Burwood.
1873	P 1	**Trebeck, Prosper N., J.P., 2 O'Connell-street.**
1879		Trebeck, P. C., 2 O'Connell-street.
1877		‡Tucker, G. A., Ph. D., c/o Perpetual Trustee Company, 14 O'Connell-street.
1895		Van de Velde, Clement, C.E., (Diploma University Ghent), Wynyard Buildings, City.
1883		Vause, Arthur John, M.B., C.M. *Edin.*, 'Bay View House,' Tempe.
1884		Verde, Capitaine Felice, Ing. Cav., Via Fazio 2, Spezia, Italy.
1890		Vicars, James, M.C.E., A.M.I.C.E., City Surveyor, Adelaide.
1892		Vickery, George B., 78 Pitt-street.
1876		Voss, Houlton H., J.P., c/o Perpetual Trustee Company, 14 O'Connell-street.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-st.
1891		Walsh, Henry Deane, B.E., T.C. *Dub.*, M. Inst. C.E., Supervising Engineer, Harbours and Rivers Department, Newcastle.
1895		Ward, James Wenman, 271 Bourke-street.
1867		Ward, R. D., M.R.C.S. *Eng.*, West-street, St. Leonards.
1891		Ward, Thomas William Chapman, B.A., B.C.E. *Syd.*, 'Roslyn,' Toxteth Road, Glebe Point.
1883		Wardell, W. W., F.R.I.B.A., M. Inst. C.E., 'Upton Grange,' St. Leonards.
1877		Warren, William Edward, M.D., M.Ch. Queen's University *Irel.* 265 Elizabeth-street, Sydney.
1883	P 4	Warren, W. H., Wh. Sc., M. Inst. C.E., Professor of Engineering, University of Sydney, p.r. 'Undoona,' Albert Road, Strathfield.
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, 5 Richmond Terrace, Domain.
1891		Watkins, Sydney C., M.R.C.S *Eng.*, Manly.
1876		Watson, C. Russell, M.R.C.S. *Eng.*, 'Woodbine,' Erskineville Road, Newtown.
1859		Watt, Charles, Parramatta.
1876		Waugh, Isaac, M.B., M.C. *Dub.*, T.C.D., Parramatta.

Elected		
1866		Webster, A. S., c/o Permanent Trustee Co. 16 O'Connell-st.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Borough Engineer, Town Hall, Marrickville.
1867		Weigall, Albert Bythesea, B.A. *Oxon.*, M.A. *Syd.*, Head Master of the Sydney Grammar School, College-street.
1881		‡Wesley, W. H.
1878		Westgarth, G. C., Bond-street, p.r. 59 Elizabeth Bay Road.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, 'Oaklands,' Edgecliff Road,
1892		White, Harold Pogson, Assistant Assayer and Analyst, Dept. of Mines, p.r. Brown's Road, Kogarah.
1877		‡White, Rev. W. Moore, A.M., LL.D., T.C.D.
1874		White, Rev. James S., M.A., LL.D. *Syd.*, 'Gowrie,' Singleton.
1888		White, The Hon. Robert Hoddle Driberg, M.L.C., Union Club, p.r. 'Tahlee,' Port Stephens.
1884		Wiesener, T. F., 334 George-street.
1878		Wilkinson, Rev. Samuel, 'Regent House,' Regent-street. Petersham.
1883		Wilkinson, W. Camac, M.D. *Lond.*, M.R.C.P. *Lond.*, M.R.C.S. *Eng.*, Liverpool-street.
1876		Williams, Percy Edward, The Treasury.
1878		Wilshire. James Thompson, F.L.S., F.R.H.S., J.P., 'Coolooli,' off Ranger's Road, Shell Cove, Neutral Bay.
1879		Wilshire, F. R., P.M., Berrima.
1891		Wilson, Robert Archibald, M.D. *Glas.*, Mast. Surg. *Glas.*, 2 Booth-street, Balmain.
1890		Wilson, James T., M.B., Mast. Surg. Univ. *Edin.*, Professor of Anatomy, University of Sydney.
1873		Wood, Harrie, J.P., 'Beverley,' 15 Mansfield-st., Glebe Point.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road.
1876	P 1	Woolrych, F. B. W., 'Verner,' Grosvenor-street, Croydon.
1881		Wright, Frederick, M.P.S., c/o Messrs. Elliott Bros., Limited, O'Connell-street, p.r. Harnett-street.
1872		Wright, Horatio G. A., M.R.C.S. *Eng.*, L.S.A. *Lond.*, 4 York-street, Wynyard Square. *Hon. Treasurer.*
1893		Wright, John, C.E., Toxteth-street, Glebe Point.
1879		Young, John, 'Kentville,' Johnston-street, Leichhardt.

Honorary Members.

Limited to Twenty.

M.—Recipients of the Clarke Medal.

1878		Agnew, Sir James, M.D., Hon. Secretary, Royal Society of Tasmania, Hobart.
1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1895		Bunsen, Professor Robert Wilhelm, For. Mem. R.S., Heidelberg.
1875	M	Ellery, Robert L. J., F.R.S., F.R.A.S., Government Astronomer of Victoria, Melbourne.
1887		Foster, Michael, M.D., F.R.S., Professor of Physiology, University of Cambridge.

Elected		
1875	M	Gregory, The Hon. Augustus Charles, C.M.G., M.L.C., F.R.G.S., Brisbane.
1875	P 1 M	Hector, Sir James, K.C.M.G., M D., F.R.S., Director of the Colonial Museum and Geological Survey of New Zealand, Wellington, N.Z.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., late Director of the Royal Gardens, Kew.
1892		Huggins, William, D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill,. London, S.W.
1888	P 1 M	Hutton, Captain Frederick Wollaston, F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1875	M	M'Coy, Frederick, C.M.G., D.Sc., F.R.S., F.G.S., Hon. M.C.P.S., C.M.Z.S., Professor of Natural Science in the Melbourne University, Government Palæontologist, and Director of National Museum, Melbourne.
1875	P 6 M	Mueller, Baron Ferdinand von, K.C.M.G., M.D., Ph.D., F.R.S., F.L.S., Government Botanist, Melbourne.
1894		Spencer, W. Baldwin, M.A., Professor of Biology, University of Melbourne.
1888	P 2 M	Tate, Ralph, F.G.S., F.L.S., Professor of Natural Science, University, Adelaide, South Australia.
1895		Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S., Parkstone, Dorset.
1875		Waterhouse, F. G., F.G S., C.M.Z.S., Adelaide, South Australia.

Corresponding Members.

Limited to Twenty-five.

1886	Marcou, Professor Jules, F.G.S., Cambridge, Mass., United States of America.

Obituary.

1895.

Hon. President.

His Excellency Sir R. W. Duff, P.C., G.C.M.G.

Honorary Members.

1876	Cockle, Sir James, F.R.S.
1879	Huxley, Rt. Hon. Professor, F.R.S., P.C.
1883	Pasteur, Louis, M.D., For. Mem. R.S.

Corresponding Member.

1880	Clarke, Hyde, V.P. Anthrop. Inst.

Ordinary Members.

1876	Campbell, Dr. Allan
1876	Dight, Arthur
1882	McGillivray, Dr. P. H.
1881	Manning, Sir William Montague
1878	Nolan, John
1890	Olliff, A. S.
1886	Sager, E. E.
1876	Sedgwick, Dr. W. G.
1891	Sutherland, Dr. G. W.

JOURNAL & PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES.

EDITED BY

THE HONORARY SECRETARIES.

THE AUTHORS ARE PARTLY AND ALONE RESPONSIBLE FOR THE OPINIONS EXPRESSED THEREIN.

Mo. Bot. Garden,
1896.

SYDNEY
PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH.
LONDON
GEORGE ROBERTSON & Co.,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.

F. White, Typ., Sydney.

ANNIVERSARY ADDRESS.

By Professor THRELFALL, M.A.,

Professor of Physics in the University of Sydney.

[*Delivered to the Royal Society of N. S. Wales, May 1, 1895.*]

ON looking back through the goodly list of twenty-eight volumes which form the Journal of the Royal Society of New South Wales, I find that it has been customary for your President in vacating the chair, to address you in the first place on the affairs of the Society, and in the second on such matters of general scientific interest as may have attracted his attention. I propose to follow the example which my predecessors have set, and shall accordingly commence with some notes on the history of the Society during the past year. In this matter I have had the advantage of the assistance of our indefatigable Assistant Secretary, Mr. W. H. Webb, for which assistance I desire to thank him.

It is a matter of congratulation, that in spite of the bad times, our numerical strength has only fallen from four hundred and forty-five to four hundred and twenty. During the year we have elected eighteen members; we have lost twenty-seven by resignation, seven through default in payment of subscription; ten ordinary and one honorary member through death; the complete list of the last is as follows:—

Ordinary Members:

Dixson, Craig, M.D., elected 1880.
Hall, R. T., elected 1878.
Hills, Robert, elected 1879.
Jones, E. L., elected 1877.
Low, Andrew S., elected 1880.
Manning, Hon. Sir W. M., M.L.C., elected 1881.
Montefiore, E. L., elected 1875.

Murnin, M. E., elected 1865.
Nowlan, John, elected 1878.
Quodling, W. H., elected 1876.

Hon. President :

His Excellency Sir R. W. Duff, P.C., G.C.M.G.

Sir Robert William Duff accepted the office of Honorary President of our Society soon after his arrival in the Colony. His official duties prevented him from taking an active share in the conduct of our affairs; we can only add our share to the tribute of sympathy and regret which came from the whole Colony at the death of a kindly gentleman.

The financial position of the Society may be regarded on the whole as satisfactory. Our total receipts during the year ending March 31st, 1895, were £1,234 10s., and we commenced with a balance of £63 12s. 3d., making in all £1,298 2s. 3d., of this we spent £1,140 17s. 4d.; we have transferred £106 14s. to the building fund, and carried forward £50 10s. 11d. to next year. Of the amounts expended we have only been able to devote about £100 to the purchase of books and periodicals, though the general library expenses, including binding, may be put at about £200. The publication of our Journal has cost us a little over £300; and we may look forward to this source of expense increasing as time goes on and the influence of the University extends. Those whose business it is to consult the proceedings of learned societies must have noticed the enormous rate at which the bulk of these works increases year by year, and our own journal has swollen with the rest. It will soon become a matter for consideration as to whether we are to go on increasing our expenditure in this direction, or limit it by publishing papers of exceptional interest only. No great saving can be made in the preparation of plates and engravings, for we have always employed cheap processes of reproduction; financial stress appears to have driven the Royal Society of London to reproduce plates in a manner similar to that which we adopt, but this must always be a source of regret to

those who have been used to the artistic beauty of their engravings, and is in my opinion quite unworthy of the leading scientific society of a great country.

The prize essay awards have cost us £50, and in my mind the time has now come for us to reconsider the whole question of spending any part of our limited means in this direction. In spite of the possibly valuable papers which the offer of rewards has brought us, I am inclined to think that scientific investigation might be more efficiently assisted by devoting the money at present spent on awards to the purchase of apparatus or material for those who require such assistance, or in improving our library. It is right I should add that this is my individual opinion only, and that I know my views are not shared by several members of the Council, whose opinion I value.

An inspection of the Society's house discloses the fact that considerable repairs will be required during the current year, and we must expect to have to meet a heavy charge on this account. The matter is engaging your Council's attention.

Turning to our building fund, we find that it is increasing slowly, and now reaches the sum of £1,286, which is invested on fixed deposit at the Union Bank. The Council has devoted a considerable time to the question of the investment of this fund, and it is possible that it may be found desirable to vary the mode of investment, provided that an eligible security can be found. It must not be forgotten, however, that our present premises are becoming too small for the accommodation of the library, which even now makes the conduct of the office work difficult by trenching on the Assistant Secretary's room. Some temporary relief has been afforded by storing books behind the dais in our meeting room, but the time is not far distant when the building fund will have to be employed in providing us with the actual space which we require.

The Clarke Memorial Fund and the Abercromby Fund stand respectively at £360 and £68, and require no special comment.

During the year we have held seven general meetings, at which thirty-two papers were read. This is an average of about four and a-half papers per meeting. On several occasions, if not on all, the time at the disposal of the writers of papers has not been sufficient for an adequate presentment of the results of their labours, and discussion has had to be compressed within very narrow limits. It appears therefore, that in the event of our continuing to receive so many valuable contributions, we must either refer more of them to the sections, or hold more meetings. The former course is in my opinion rather undesirable, for it must mean the banishment of perhaps the most important and interesting communications to sectional meetings, while the full meetings would be occupied in dealing with those subjects only for which no sections are appropriate. If we increase our general meetings to two per month, it would I think be easy to arrange for the division of subjects into two groups, and apportion one meeting per month to each, in this way an engineer would not require to sit through a paper on anthropology, etc., in order to hear one in which he was interested, or vice versa.

I do not propose to append a list of papers read during the year for out of the thirty-two, twenty-eight will be found published in the journal, and the other four may be published with those we shall receive during the current year. The list of exhibits will also be found in its proper place.

During the year the average attendance of members was thirty-seven, and visitors four, so that our meetings have certainly not lost in interest. The activity shown in the sectional meetings, especially on the Medical and Engineering sides, forms a subject for congratulation. The engineering section held eight meetings and the medical three meetings. The interest shown in the engineering section may be judged of by the fact that only two papers were read at the sectional meetings, the whole of the rest of the time being devoted to discussion. It is not too much to say that the engineering section is certainly the most important meeting-ground of engineers in the Colony.

With regard to the conversazione held at the University on December 5th last, we may congratulate ourselves on having achieved a success. At no previous time were the exhibits more numerous or interesting, though the removal of many of them from the Great Hall of the University to the Laboratories, naturally rendered the exhibition so large that few people could have seen everything. Amongst a number of most excellent exhibits perhaps Mr. Russell's magnificent stellar photographs, exhibited by means of a magic lantern, were the most striking. About six hundred visitors and members were present, and the cost was only £70.

Library.—It was stated above that the cost of the library might be put at about £200, excluding superintendence. The actual outlay was £173 9s. 10d. We exchanged our journal with three hundred and ninety-five kindred societies, receiving in return one hundred and ninety-six volumes, one thousand and fifty-eight parts, fifty-nine reports, one hundred and fifty-two pamphlets, one atlas of geological charts, fourteen hydrographic charts, and fifty-four meteorological diagrams, a total of one thousand five hundred and thirty-four publications. The "Institut de Carthage" of Tunis has been added to the exchange list.

Clarke Medal.—At the meeting of the Council on the 31st October last, it was resolved that the Clarke Memorial Medal for 1895 be awarded to each of the following gentlemen :—Mr. Robert Logan Jack, F.G.S., F.R.G.S., Government Geologist, Queensland, and Mr. Robert Etheridge, Junr., Government Palæontologist, Department of Mines, Sydney.

Hon. Member.—At the General Monthly Meeting of the Society held 3rd October last, on the recommendation of the Council, W. Baldwin Spencer, M.A., Professor of Biology, University of Melbourne, was unanimously elected an Honorary Member of the Society.

Original Researches.—In continuation of the practice originated in 1881 to publish yearly a list of subjects peculiar to Australia,

the investigation of which would be of great interest and value to the Colony, the Council invited original contributions and offered its medal, together with a grant of £25, for the best original paper on the following subjects, viz.—

Series XIII.—*To be sent in not later than 1st May, 1894.*

No. 43—On the Timbers of New South Wales, with special reference to their fitness for use in construction, manufactures, and other similar purposes.

No. 44—On the Raised Sea-beaches and Kitchen Middens on the Coast of New South Wales.

No. 45—On the Aboriginal Rock Carvings and Paintings in New South Wales.

One paper was received on subject No. 43. Two papers were sent in on No. 44, the first of which could not be received the writer having failed to comply with the conditions laid down, and the Council did not consider the second one of sufficient merit to receive the reward. One paper was received on No. 45.

At the meeting held 25th July, the Council awarded the prize of £25 and the Society's medal to the writers of the following papers:—1. "On the Timbers of New South Wales" by "Experto crede," Mr. J. V. de Coque, Roads and Bridges Branch, Public Works Department. 2. "On the Aboriginal Rock Carvings and Paintings in New South Wales" by "Cæsar aut nullus," Mr. R. H. Mathews, L.S., Parramatta.

The list of subjects for prizes now offered is, as follows:—

Series XIV.—*To be sent in not later than 1st May, 1895.*

No. 46—On the Silver Ore Deposits of New South Wales.

No. 47—On the Physiological Action of the Poison of any Australian Snake, Spider, or Tick.

No. 48—On the Chemistry of the Australian Gums and Resins.

Series XV.—*To be sent in not later than 1st May, 1896.*

No. 49—On the origin of Multiple Hydatids in man.

No. 50—On the Occurrence of Precious Stones in New South Wales with a description of the Deposits in which they are found.

No. 51—On the effect of the Australian Climate on the Physical Development of the Australian-born Population.

Series XVI.—*To be sent in not later than the 1st May, 1897.*

No. 52—On the Embryology and Development of the Echidna or Platypus.

No. 53—The Chemical Composition of the Products from the so-called Kerosene Shale of New South Wales.

No. 54—On the Mode of Occurrence, Chemical Composition, and the Origin of Artesian Water in New South Wales.

Abercromby Fund.—The prize of £25 offered by the Hon. Ralph Abercromby for the best essay on "Southerly Busters" was awarded by the Committee to Mr. Henry A. Hunt, Second Meteorological Assistant, Sydney Observatory.

During the past year considerable activity in the pursuit of knowledge has been exhibited. Much of the work done has been reported in the Journal by our Society, and in the proceedings of the Linnean Society. The following particulars are appended, but the list does not profess to be complete, as some difficulty has been experienced in obtaining information.

In the observatory the regular astronomical and meteorological work has been fully maintained, owing to the increased sensitiveness of the plates now used, which make it possible now to do in one minute what used to take eight minutes, when this work was begun in 1890, thus virtually increasing the size of the camera eight times. One thousand one hundred and forty photographs of astronomical objects have been taken. Nine hundred and forty-six of these were devoted to the photographic survey of the heavens, and complete the Sydney section of that work for catalogue purposes. Seventy-nine photographs have been devoted with very satisfactory results to the investigation

of nebulae and nebulous places, and star clusters, comets, etc. The transit of Mercury was satisfactorily observed. A valuable series of cloud photographs of typical forms has also been taken for the more accurate study of weather conditions in Sydney. These show that the clouds here come under the usual classifications, but have a distinctly local stamp.

During the year the original Kater pendulums were swung in the observatory by Mr. Love, Demonstrator to the Professor of Physics at Melbourne, acting for the Gravity Committee of the Royal Society of Victoria, and the opportunity was taken to carefully test the stability of the frame on which they are swung with extremely satisfactory results. The apparatus was sufficiently delicate to show a flexure in a massive cement-concrete floor produced by a 14lb. weight, but did not show the slightest flexure in the pendulum supports when the pendulum was in motion.

The ten feet standard bar of Queensland has been fully compared with the two standard ten feet bars of New South Wales. A new chart of southern circumpolar stars has been prepared and published, and an Act of Parliament providing for the adoption of standard time on February 1st, 1895, was carried into effect on that day; and now New South Wales, in common with Victoria and Queensland, use the time of the 150° Meridian east of Greenwich.

The results of the study of ocean currents on the coasts of Australia during the past twelve years have been published, and a special effort made to interest captains of ships trading to Australia in ocean currents and meteorology with much success.

At the Technological Museum the Director and his staff have been engaged chiefly on the following works:—Additions to the systematic botany of the Colonies, investigation of the chemistry of some of the vegetable products of the Colony, especially the eucalyptus oils and the barks of certain trees from Queensland; classification of the collections of economic geology; economic

entomology ; literary work dealing with the flowering plants of the Colony.

At the University the following subjects have been investigated, or are in progress of investigation :—

Biology.—Development of marsupial teeth.

Physics.—Magnetic properties of bismuth, gravimetric work. Electrical properties of selenium.

Chemistry.—Investigations on occurrence of gold and allied chemico-mineralogical matters. On the specific gravities of some gem stones. On the separation of gold, silver, and sodium from sea water by muntz metal sheathing. On certain new minerals. On the occurrence of gold in the Hawkesbury Rocks about Sydney. On variations in the amount of ammonia in waters on keeping. On the corrosion of aluminium. On crystallised carbon dioxide. On the waterproofing of bricks and sandstones with oils. On the porosity of cements and plasters.

Engineering.—Tests of the strength of materials, chiefly colonial timbers and cements.

Geology.—Examination of volcanic glasses of the Tweed district. Geology of the Macdonald Ranges. Evidences of the Palæozoic Ice Age in Australia.

Physiology.—The physiological action of snake venom. Coagulation of the blood. Colouring of wool by micro-organisms.

As one of what I may, perhaps, be permitted to call the current generation of Physicists, I feel that no account of the history of physical science of the last few years would be adequate which did not place the death of Helmholtz in the foremost place. It is, perhaps, impossible for the present generation of Physicists who have been born and bred in the doctrine of the conservation of energy, to estimate at its true value the assistance they have received at all stages from this all-embracing generalization. The physics presented to us from our earliest youth was already a definite structure of which the "Erhaltung der Kraft" was the very corner stone. It is not true to say that

the principle was discovered by Helmholtz—but for some reason on other his essay seems to have had greater persuasive powers than the work of other and earlier labourers in the same field. The reason of this was in my opinion—and I offer it with the utmost diffidence and every possible reservation—that he was the first to recognise that change of the potential function is in a certain aspect the measure of a distinct entity, viz.—that knowable, but unknown thing potential energy—thus christened by Rankine. But Helmholtz's claims to immortality, rest on a broader basis than is afforded by any one discovery. He laid the foundation of that science of Bacteriology, which promises to assist mankind in coping with his environment more powerfully than any discovery since the steam engine. It is understood that Ophthalmic surgery is based largely on his work on Physiological optics. Electrical theory is indebted to him not only for many notable discoveries but for the training and inspiring of Hertz. To his mathematical powers we owe the theory of vortex motion, and many important advances in Hydrodynamics. His great "Tonenempfindungen" in which he appears as Physicist, Physiologist, Anatomist, and Psychologist might well have been the life work of an ordinary mortal, to him it was a mere episode. There was a time when we hoped that he had built the bridge leading from the physical and mathematical theory of sound to the doctrine of harmony, but fate has been against this courageous and ingenious effort, and at the present time it is very doubtful if it can be said to have materially advanced the position. The energies of Helmholtz's later life were partly absorbed in the councils of his country; and partly devoted to the organisation of the great testing and standardising Laboratory at Charlottenburg.

Though it is generally desirable to subdue the personal element as far as possible; on an occasion of this kind I feel that perhaps the members present might like to know something of the personality of this, probably the most versatile and learned philosopher that ever lived. In the winter of 1888 I presented myself at

the house attached to the Physical Laboratory of the University of Berlin, armed with an introduction to Von Helmholtz. I was contemplating devoting many years, perhaps all my life, to the investigation of physico-chemical problems, and I wished to hear what Helmholtz would have to say as to the utility of such an undertaking. I presently found myself in a study of extraordinary neatness and of a sumptuous yet forbidding aspect, and in the presence of a soldierly-looking old man. I should have taken him for an officer of engineers had I not often seen his portrait. I stated my business without preamble. He considered awhile, and then declared it to be his opinion that the next advance must be made in the border land of chemistry and physics, especially on the electrical side, and that I could not hope to advance our knowledge better than by doing as I proposed. He spoke in German, and I in English, for our mutual convenience, and gave me an indescribable impression of being before all things a man of business-like habits and rapid, decisive action—a soldier, in fact, in the best sense of the word. It was with something not unlike relief that I bowed myself out of his presence, and, as I walked away, I thought I understood the man who many years ago criticised the English University fellowship system, and regretted that so much money produced so little scientific work "amongst the well-nurtured youth of the British Isles." His theory was that English students had not during their training been brought in contact with the "living spirit of research," and he recognised that in physicai science stagnation means retrogression, and that the man who has not the curiosity to attempt to widen our common knowledge is not fit to set himself up as a teacher, nor are the pupils of such a man likely to receive any lasting benefit. If Helmholtz's words, so fruitful first through Germany and France, and then through England and America, could find even at this late date some echo in the Colony, we might be gradually educated up to seeing that the commercial value of a teacher is not to be measured by the number of hours of lecture that can be dragged out of him,

nor is a laboratory to be regarded as an expensive luxury to be blown away at the first breath of retrenchment. The time when the "Geist des Forschers" will be reverenced as the supreme weapon in the fight of mankind against the forces of nature is not yet, but it will surely come, and woe to that nation that learns it last.

I turn to a very different personality in approaching Helmholtz's great pupil, the simple, gentle, kindly Heinrich Hertz. Nearly all the electrical work of importance of the last six years—for I do not include such things as dynamo making, or transformer testing—has been on the lines laid down by Hertz in his study of electro-magnetic waves. I do not propose to detain you here by referring to those researches, for I gave an account of them before the Australian Association for the Advancement of Science in 1890 at the Melbourne meeting, and shall have something to say about them again presently; rather will I refer to the man himself. Hertz began life as an engineer, but his taste for physical work was too strong, and he gradually drifted into Helmholtz's laboratory, where his powers were soon appreciated, and where he began that study of electro-magnetism which ended in persuading Continental philosophers of the truth of Maxwell's mechanical theory of electricity. I say Continental philosophers advisedly; for in England and America (for in this matter America is Rowland), the theory had taken firm root, and though Hertz supplied much interesting confirmation and opened up an experimental road of vast interest, it cannot be said that he did more then confirm what we had always believed. In character Hertz was probably one of the most kindly and gentle men that ever lived, and just as his work has that peculiar directness and simplicity that characterises the work of Faraday and of Darwin, so was he himself a man of much the same character—*i.e.*, the highest reached by the human race. He died on New Year's Day, 1894, the brightest and best beloved of physicists.

On May 21st, 1894, there died August Kundt, Professor of Physics in Berlin, formerly in Strassburg. Though I expect his

name is unknown to many present here to-night, that must be regarded as a mere local misfortune. Kundt was one of the most brilliant of modern experimentalists, and made great advances in acoustics, optics, and magneto-optics. It is of interest to note that the monatomic and probably elemental character of argon discovered during this year was established (in so far as it is established) by a method invented by Kundt. Exact information has not yet come to hand as to the method employed, but as Kundt's method is probably the best available in dealing with small quantities, it is pretty safe to assume that it was employed in this instance. To Kundt the rapid rise of the University of Strassburg is in great measure due, and to his energy we owe one of the finest physical laboratories in the world. Before all things, Kundt was what the Germans call "gemüthlich"—a jolly fellow. His method of teaching was copious and admirable conversation in the laboratory, and there probably never was a teacher who had so strong a hold upon his pupils—a hold both of heart and head. There was nothing in the way of experimenting he could not do; his spirits were always at boiling point; he was never seen without a smile on his face, or heard to breathe an unkind word. He had a magnificent adoration for the work of Faraday; in all things he was eager—a great human lion with flowing hair and beard, and inexpressible good humour. He was a thorough German, too. His surprise at seeing me, a man who had been to Australia and actually returned, was exquisite. He was even late for lecture to celebrate the event. "Eheu fugaces"—the least of all thy servants bids thee adieu dear master, there is no other man like thee. Helmholtz, Hertz, Kundt—what a gap their loss makes!

* * * *

I now propose to give a brief account of some of those advances which have been made in physical science since I last had an opportunity of compiling a report, viz., in 1889. It must be understood, however, that I do not profess to refer to every research of importance, for no address could contain more

than a bare enumeration of them, nor do I claim anything except indulgence for the choice I make. I can only deal with those matters coming under my immediate notice which seem to me individually to be of the most importance, and I have given a preference for work done within the last year.

Commencing with electricity, the road marked out by Hertz has been followed by a host of observers who have devoted themselves to the examination of both stationary and progressive wave fields. The general results up to last year are contained in a work on "Recent Researches in Electricity and Magnetism," by Professor J. J. Thomson, of Cambridge—a work intended as a supplement to Maxwell's immortal volumes, and forming, in fact, a "third volume" worthy of the other two. The production of this work is probably the most important electrical event of the last five years.

In order to take up the story of electrical developments I must briefly refer to the state of the subject where it was left by Hertz. Maxwell had given sound reasons for believing that electric force is a quantity propagated, not instantaneously through space, but at a finite though very rapid rate. If a conductor, therefore, could be charged, discharged, and charged again in an opposite manner each feature of the process could be followed at a distance—a sufficient interval of time being allowed to elapse for the propagation from the source to the point in question. If this process can be repeated regularly, we shall have a succession of corresponding states at the point of observation, in every essential similar to the succession of states as to vertical position passed through by a cork floating on water over which a train of waves is passing. If the regular process be repeated very rapidly, we have according to Maxwell, a series of electric waves—or periodically varying electric conditions—propagated outwards with the velocity of light and, in fact, constituting light itself. Now this electrical theory of optics, the electro-magnetic theory as it is generally called, was found to fit in with observation on light, very well indeed on most essential points, but it

undoubtedly seemed to be opposed by other results, almost equally trustworthy and important. In consequence of this discrepancy—for without it the theory must have been only read to be accepted—many philosophers waited for "more light" and in the meanwhile worked at matters not immediately depending on any theory, such for instance as the exact fixation of the electrical units. I will not detain you by referring to the process of thought by which Hertz was led to study electrical waves produced by purely electrical means, and of a length enormously greater than the vaves of light: suffice it to say that he discovered a means of producing such waves and was able to show that they actually existed and behaved as Maxwell had indicated. At the same time, being anxious to establish the main points, Hertz, with that rare insight which in experimental work is the chief test of genius, laid aside a number of anomalies and unexplained results. His followers naturally took up these points and ran them down. The first thing was to get some means of detecting the nodal points more simple and convenient than the spark gap used by Hertz, and accordingly we now have an abundance of such means. The latest, the simplest, the most delicate is probabably a tube of filings regarded as constituting part of an electrical circuit and whose resistance, viz., that of a large number of bad or "microphone" contacts is found to be affected by electrical waves. It was observed by M. Edouard Branly in 1890* that a bit of glass covered with "porphyrised" copper had its resistance enormously diminished if it was placed near to a discharging Leyden jar. A similar observation as to the improvement of a shaking contact under the influence of electrical waves had been noticed in 1889 by Prof. Lodge.

If a tube of filings be arranged as one arm of a Wheatstone's bridge, then it is found that the resistance is diminished by the impact of even feeble electrical radiation. On tapping or shaking the tube, the old resistance approximately reappears. It has long been known that commercial selenium in the

* C.R. 111, page 785, and 112, page 90.

crystalline or dull grey form, has its resistance altered by the incidence of light waves and recovers somewhat slowly, and that it is sensitive to radiation of somewhat limited range as to wave length. Curiously enough, Professor Lodge has noticed that tubes of filings are sensitive also to waves of a more or less definite wave length, but of course on a much larger scale. This gives us incidentally a hint as to a possible cause of the light sensitiveness of selenium.

In addition to the loose contact method we now have a large number of others, some on the "trigger principle," in which a small spark precipitates a greater from a convenient source, some involving the use of a galvanometer, some an electrometer, some using vacuum tubes, others the heating of wires—a whole host of methods whereby the study of electrical waves may be facilitated.

Among the phenomena discovered by Hertz, none have given rise to so much uncertainty as the apparently contradictory results obtained by different observers as to the velocity of waves concentrated in space by means of wires. These doubts have practically been set at rest by investigating the expectedly large influence of the walls and floor of the rooms in which experiments have been made. The ambiguity from this cause was removed before Hertz's death. Another trouble arose as to the question whether the waves observed had a wave length depending on the natural period of the oscillator, or on that of the receiver. These questions have been considerably elucidated by a consideration of the general conditions of a vibrating system subject to damping, whence it appears that a heavily damped oscillator or exciter—or, in other words, one which emits energy very fast—can only give one or two waves appreciably affecting the resonator, whose "free" period then becomes of chief importance. The wave length observed in experimental work accordingly depends on whether the exciter or receiver is the more heavily damped.

If we look at the matter from the point of view of the resonator, we see that a resonator will respond almost equally well to vibra-

tions of widely different periods if only it be of such a type that when speaking itself it is heavily damped. The sounding board of a piano or the body of a violin, or indeed the air in the ear passages of any animal, is such a body. If on the other hand the resonator be only slightly damped, it will require much greater accuracy of tuning to set up resonance, but when once this is attained the resonance will be much stronger. In acoustics a tuning fork or closed organ pipe is a resonator of the class to which I allude. In the electrical case, so far as I understand it, the matter is made more complex by the fact that both electric and magnetic energy are radiated, and one kind of radiation may, and generally does, proceed faster than another, so that a vibrator may be heavily damped as far as electrical radiation is concerned, and only slightly so far as magnetic energy is concerned, and vice versa. Ultimately the energy per unit volume of both kinds will be equal in the wave field, but meanwhile the effects may become too attenuated for observation. We owe a good deal to Bjerknes* in this connection. A clear but brief account is also given of the leading results in the Archives des Sciences Physiques et Naturelles de Genève—a most useful and pleasant publication. By the application of the principles just referred to, the study of electro-magnetic waves as produced by resonators of varying form is greatly assisted, and most if not all of the outstanding difficulties have now been removed. This brings me naturally to a consideration of the brilliant work of Nikola Tesla in this field—work which exhibits the highest genius at every step. The advance made by Tesla is briefly this. Hertz worked with comparatively short waves which damped down after a very few vibrations, occupying a time perhaps in all of the order of the ten millionth of a second. With the apparatus used by Hertz the phenomena only occurred perhaps forty times a second, so that the time occupied by the phenomenon itself was only a very small fraction of the whole time involved, just as if one were to ring a bell for a minute every year and endeavour to deduce

* Wied. Ann. 44, p. 74.

acoustical principles from its performance. Tesla, with immense experimental resources behind him, succeeded in constructing apparatus which, while emitting longer waves, and waves which were less damped, repeated the process much oftener, so that referring to the analogy again, the bell might be supposed to be kept ringing a considerable fraction of the time. With this radiation Tesla was enabled to perform experiments of a quite new order—especially in high vacuum lamps—where an electrostatic discharge (in old fashioned language) was caused to converge on infusible bodies, such as carbon or carbon silicide. Incidentally it turned out that air ceases to act as an insulator for such high frequencies, and this is probably the greatest drawback to the utilisation of such radiation for lighting purposes. Within the last two or three years the matter has been taken up by E. Wiedemann and Ebert, who find that in a high vacuum the discharge produced by almost continuous but individually feeble oscillations is capable of exciting the phosphorescence of certain substances in a most remarkable manner. As I believe that it is legitimate to hope for improved means of illumination in this direction, and as I know that this is a subject interesting to most people, I will refer to Ebert's arrangements rather more closely.

A description of the apparatus employed is given in Wiedemann's Annalen, Vol. LIII, fig. 144, and it may be regarded as a simple arrangement of a Tesla apparatus for small output combined with an arrangement for securing very persistent oscillation. It may be mentioned in passing, that though the energy of an electrically vibrating system is greater, the greater the capacity—still the damping is in general greater also—so that if one wants to keep the oscillations going, one must not use too great capacities; while on the other hand too small capacities must not be employed, or the energy available becomes too small. This is independent of the frictional damping or loss in the apparatus itself which depends directly on the resistance. The apparatus on the table is an exact copy of that described by Ebert. It consists of a "spark gap" fed in any suitable manner, (by a Wimshurst machine in this

case) and two primary condensers arranged in Lodge's manner, the "outer coatings" forming the terminals of the primary of a small induction coil. The secondary of the coil terminates in another condenser, from which the leads pass to the lamp. All the condensers are adjustable. Another point about it is that in order to secure a minimum of damping, the primary and secondary circuits are turned to respond as closely as possible, as indeed must follow from the general principles laid down above. The oscillations are produced by the discharge of the primary air condensers arranged in the most symmetrical fashion. Ebert considers that the loss observed in condensers having dielectric materials other than air is due to what is now generally called the "hysteresis" of the dielectric. I do not think that this is necessarily the case, but it may pass. The ends of the secondary circuit are connected to external electrodes surrounding or partially surrounding an exhausted globe in which is placed the phosphorescent substance. This substance is then excited by the radiation from the electrodes or rather by the kathode rays starting from inside the glass under the electrodes and falling on the luminous paint.

The phosphorescent substance which Ebert uses, he describes as the "blue-green luminous paint," made by a firm of German chemists. The most interesting point in connection with the matter to the general reader, is the extraordinary efficiency of such a lamp, as claimed by Ebert. Everybody who pays for his electricity by meter knows that an ordinary 16 C.P. lamp uses up energy at a rate of about sixty watts; or say one-twelfth of a horse power. In other words, if no energy were wasted between an engine and the lamp, each horse power developed by the engine would keep about twelve lights of 16 C.P. going; of this energy however, vastly little affects our eyes—not more than say five per cent. But all energy affecting the eye does not affect the eye equally; it takes, according to Langley, about one hundred thousand times as much energy to produce perceptible vision with red light as with yellow-green light. The ordinary incandescent lamp however is rather poor in yellow-green rays,

so that not only does ninety-five per cent. of the energy coming from such a lamp refuse to affect our eyes at all, but the greater part of what does so affect them does it by means of rays to which they are only slightly sensitive. That a much higher efficiency is attainable we know by Langley's study of the glow worm, the most efficient lamp in existence, for the heating power of the energy emitted is too small to be measured by ordinary means, or a glow worm "burns cold." Ebert claims that his lamp will give a 'serviceable' light for an expenditure of a millionth of a watt. Suppose 'a serviceable light' means half a candle power, then for a fifteen candle power lamp we should require only three hundred thousandths of a watt, instead of the fifty watts say we require at present; of course further experience may show that this estimate of Ebert's is too small, but it is possible, and in any case there is no doubt that an enormous efficiency is gained. This is not quite new by the way, we always knew that phosphorescence was an efficient form of illumination, but the figures given, are I believe, the first to have been anything like fairly estimated. In connection with this I might remark that incandescent burners of the Welsbach type, using gas, probably work in virtue of the substance of the mantle being rendered phosphorescent by rise of temperature. Whether anything will come out of Ebert's lamp I cannot say, for the practical difficulties appear insuperable at present.

Before I leave this subject, I will mention a result I got some years ago in a discussion on sensitive galvanometers. I found that I could make an instrument so sensitive that a definite motion of the mirror corresponded to an energy supply of 10^{-9} ergs per second. This I have now increased so that an effect is produced by a supply of 10^{-11} ergs per second, or, say, 10^{-21} horse power. Langley's numbers for the most efficient light required to produce vision are about 10^{-11} ergs per second. Consequently, the human eye must look to its laurels, or its claim as the most sensitive mechanism will have to be rejected.

Though not exactly a matter of the last year or two alone, I feel I ought to refer to the work done by Wiener and by Lippmann in photographing the effects of standing waves, by which I mean the interference effects produced near to a reflecting surface by the incident and reflected trains. The objects of the two experimenters were by no means identical. Wiener deliberately tried to reproduce the experiments of Hertz, using light waves and a photographic film, instead of long electro-magnetic waves and a resonator. He succeeded in making a sensitive collodion film with a thickness of only one-thirtieth of the wave length of sodium light—*i.e.*, about one five hundred thousandth of a centimeter. By tilting this film with respect to the reflecting surface, Wiener was enabled to obtain evidence of the nodes and anti-nodes of the chemically active vibrations, in the form of interference striæ; and, moreover, was able to show that the striæ were standing wave effects, and not the ordinary interference effects of thin films. By applying the results of Trouton on the laws of reflection at the polarizing angle of electro-magnetic radiation, and assuming that the chemical effects are the outcome of the electric rather than the magnetic vibration, Wiener has been able to show that the view taken by Fresnel as to the "direction" of vibration refers to the electric vector. It has been suggested that the photographic film may be affected by the magnetic component, but most physicists would, I think, take Wiener's view of the matter, as being the more probable.

Lippmann, on the other hand, uses ordinary thick but transparent films, and obtains many nodes and antinodes in the film thickness. In this way he is able to produce a photograph of the nature of a diffraction grating, and by a train of reasoning which is exceedingly acute, though a good many hypotheses are involved, he shows that this grating photograph will yield by reflected light a colour which will correspond more or less closely with the colour of the light falling on the film originally, and this whether the colour was pure or not. Success is the only test of

work of this kind, and M. Lippmann appears to have had a fair share of it, and has actually photographed simple objects—such as a pot of geraniums, the photographs (negatives in the ordinary sense) exhibiting the colours of the original. So far as I know, he has not succeeded in printing in colours. The suggestion of the method appears to have been due to Zinker in 1868, and so is of considerable antiquity. I see no reason why we should not have coloured photographs of some kind within a reasonable period.

The next point on which I will touch refers to the use of the electric furnace, for within the last few years a magnificent series of researches has been carried out with its aid by Moissan on hitherto infusible substances. The simplest form of electric furnace merely consists of a lime block hollowed out and provided with a lid. Two carbon poles meet in the centre of the cavity, and are the seat of an arc light whose power is only limited by the engine power available. The end result is that a considerable fraction of the energy of the boiler fire is concentrated in the space of a few cubic inches, and the temperature attained is correspondingly high. By this furnace Mr. Moissan has not only been able to produce small diamonds, but he has been able to prepare considerable quantities of the metals of the chromium group, (and lately with an improved furnace of titanium), which, it is not too much to say, were unknown hitherto in any thing approaching an ingot form. The latest development appears to be the manufacture of calcium carbide from lime and coal dust. This process we owe to Mr. Willson, an American, and it appears likely to have some influence in the arts; for the massive calcium carbide, when acted on by water, yields acetylene in a very pure state, and this either as a means of enriching gas, or as a starting point for organic synthesis is a very valuable substance. Some years ago Mendelejeff advanced a theory of the production of petroleum from its elements under the influence of high temperatures, so that Mr. Willson's discovery will come as cheering

news to those who still think that rock oil is of organic origin, and therefore not likely to exist in unlimited quantities.

A good deal of work has been done recently in improving our means of measuring temperatures. Many people think that as temperature measurements have been made for so many years they must necessarily have been carried to a high point of accuracy. In special cases such as the experiments of Regnault this is no doubt true, but the temperatures investigated did not lie much outside the ordinary range—*i.e.* up to 300° Centigrade—and the apparatus was quite unmanageable under ordinary conditions of work. Improvements have been made in two ways. The electrical resistance of platinum has been accurately determined as a function of the temperature, and it has been shown that different samples of commercially pure wire behave similarly. Platinum wire resistance thermometers are now articles of commerce. The thermoelectric couple has also been investigated by Le Chatelier for high temperatures, and a junction of platinum and a ten per cent. alloy of rhodium and platinum has been made to yield reliable results. On the other hand a most extraordinary improvement in the detail of correcting ordinary thermometers has been achieved by M. Guillaume of the Bureau International des Poids et Mesures: with the result that thermometers can now be made by a skilful Parisian maker, which after passing through the hands of M. Guillaume's assistants, will give correct readings on an actual scale of temperature to within one two-hundredth of a degree centigrade. I have such instruments in my possession.

The crowning discovery of the year however, has been that of a new component of the atmosphere by Lord Rayleigh. This gas was virtually discovered some two years ago and has now been isolated by Lord Rayleigh and Prof. Ramsay. About 1893 Lord Rayleigh began to redetermine the density of gases with a view to testing Prout's hypothesis. As a result there is now no doubt that the ratios of the atomic weights of oxygen and hydrogen do not accord with the hypothesis in question: a result which had been provisionally established by Stas for other substances.

While weighing nitrogen Lord Rayleigh found he got one density when the nitrogen was taken from air, and another when it came from chemical sources. The results of each set of observations were consistent, and after trying to explain the discrepancy in every way, Lord Rayleigh fell back on the conclusion that there must be some constituent of air hitherto unrecognised. An investigation of the basis of our knowledge of the composition of air showed that there was a possibility of a small quantity of some other substance existing in it, besides those usually considered. Accordingly the nitrogen and oxygen, water vapour, and carbonic acid were successively removed, and Raleigh and Ramsay isolated the new substance, to which they have given the name of "argon." It appears to be a singularly inert gas, (to which property it owes its late discovery), heavier than nitrogen, and most probably an element, since there is strong evidence that it is monatomic. Should this be the case, room will have to be made for it in Mendelejeffs' series—one can only pray that it may fit a vacant place and not turn the whole of chemistry upside down by refusing to come in under the periodic law. It would come in if its atomic weight were twenty, but the discoverers think it is forty. However, out of such catastrophes, advances are apt to be made, and if we have to amend our periodic law we shall probably get something better in its place, perhaps some light on the dynamics underlying it. I cannot close this brief notice without directing your attention to the magnificent triumph which this discovery has obtained for the method of enquiry by means of prolonged, laborious, and exact measurement, as opposed to the method of happy inspiration. Contrary to the popular idea, the vast majority of discoveries have been made by the methods employed by Lord Rayleigh, of which the essence is that no obscurity, however small, is to be passed over until it is completely sifted. Another reflection is as to whether this discovery does not illustrate the deleterious effects of scientific instruction out of text books, from which all of us have suffered. It is impossible to go into full detail in a text book, and consequently investigations as

reported therein are usually made to appear much more absolute in their results than is actually the fact, and a reader gradually gets to accept their conclusions as quite beyond question. In England there is a rare white butterfly which is seldom or never captured, except by little boys, for it cannot be immediately distinguished from the 'white cabbage' butterfly, and so is only taken by those who are inexperienced in butterfly hunting.—*Verbum sap.*

I have hitherto spoken entirely of matters involving new principles and capable of enlarging our general ideas. I now turn to the humbler task of referring briefly to some of those applications of science—which too frequently pass for science itself. No mistake is more fatal to progress than the idea that the discovery of application is as important as the discovery of principles, or of facts of general significance. The first matter I shall refer to is one on which an enormous amount of scientific knowledge has been brought to bear. I refer to the polyphase current. Within the year we have witnessed not only the approximate completion of the first instalment of the Niagara Electric Works, but the successful introduction of two and three phase plants elsewhere. Happily for the inventors, the greater number of the problems had been already worked out for optical purposes and form a part of the theory of "harmonic motion." The works at Niagara will always be remarkable for the extreme care which has marked every step of the undertaking. The Corporations involved have from the beginning spared no pains or money in calling to their assistance the best advice available, both for their hydraulic and electric works. Most of the machinery is novel at all events in its magnitude and in its structural detail. The most interesting point to me was the arrangement for "floating" the long vertical turbine shaft, and so dispensing with a step bearing. Prof. George Forbes, who has had to stand a rather hot fire of criticism, is to be congratulated on the success of the undertaking. Though on a very much smaller scale, a transmission of power works is now almost completed within this Colony. In

this case arrangements have been made for the transmission of about five hundred horse power from the falls of the river Gara to the mining town of Hillgrove, distant some seven miles. The system adopted in this case is the three wire direct current system, but the voltage employed, 1600, is such as has never been used before with currents of the magnitude here involved. The mere fact that a contractor was found willing to guarantee the performance of machines yielding, say 250 h.p. at over 1,600 volts, is the strongest evidence of the immense advance which has been quietly going on in the design of direct current dynamos. One of these developments of great interest is what is known as the "Sayer's winding," by which means practically no field winding is required —a most original idea.

Late last year (too late for reading at our last meeting), a paper on Cellular Kites was sent into us by Mr. Lawrence Hargrave, and I cannot let this opportunity pass without expressing my strong conviction of the importance of the work which Mr. Hargrave has done towards solving the problem of artificial flight. Mr. Hargrave's work is so well known here that I need do no more than allude to it with the remark that we may expect to see Mr. Maxim adopt the cellular principle, and thus reduce the space occupied by the aeroplanes of his machine. The problem of flight is one which requires for its solution not only a great deal of inventive capacity, but a sound knowledge of the properties of materials, and the fact that both these qualifications appear to be possessed in a high degree by those working at the subject, allows us to indulge in the most sanguine anticipations. In connection with this matter the soaring of birds has for many years formed an interesting subject of speculation. A solution of the problem has been recently obtained by Mr. Langley working on a suggestion made by Lord Rayleigh. I can say nothing about it here, except that the essence of the explanation lies in the fact that even in what one would call a steady wind there are much more important fluctuations than is generally supposed—*i.e.*, that all winds are

gusty to an unexpected degree. Lord Rayleigh supplied the idea of the use of intermittent wind, and the evidence showing that winds are, in fact, extremely intermittent has been put together by Langley, if not indeed originally discovered by him.

Before I conclude I should like to make a few remarks on that particular branch of physical chemistry in which I am chiefly interested. I refer to the electrical properties of substances. Both electricity and chemistry are in this state. Neither science can make much progress in fundamental principles without the assistance of the other. It has long been a truism that when we know the nature of electricity, we shall know a little about the fundamental mechanism of chemical action and vice versa. The extraordinary definitness of the relation between the time integral of an electric current and the amount of decomposition in an electrolytic cell through which it passes, shows how necessary a theory of electricity is to chemistry. Within the last few years a number of experimenters have been busy on the passage of electric currents through gases, with the result that there is now little or no doubt but that gaseous conduction is also electrolytic. We have no means of deciding at present whether conduction through metals is electrolytic or not, and I shall show, if time permits, that with bad conductors the probability is in favour of electrolysis. We, therefore, have the fact that, setting metallic conductors aside as ambiguous, whenever we get a conduction current we get, not only magnetic effects, but chemical effects as well; and any respectable theory of electricity must embrace them. We see, therefore, that this road, like all others, leads to our requiring to examine the relation between ether and matter, or, in other words, all physical roads in the long run lead equally to chemistry. It has been my endeavour, therefore, for many years, to elucidate some of the relations involved, but I was stopped on the threshold of enquiry by the difficulty that the electrical properties of elemental substances with the exception of metals were unknown. With the assistance of Mr. Pollock and two of my students, Messrs. Allen and Brearley, I made a beginning by

examining the properties of sulphur—a substance chosen for reasons I do not need to go into here—but which ultimately turned out to have the immense practical advantage of being commercially obtainable in a state of extraordinary purity. Most Leblanc alkali makers now recover their sulphur by the Chance process, which consists in liberating sulphuretted hydrogen from the waste and then half burning it, so as to oxidise the hydrogen and deposit the sulphur. This sulphur is generally pure to about one part in ten thousand, the residue consisting of a trace of water and dust. By melting and filtering, the dust may be removed, and then a single distillation yields a substance so pure that no tests I have been able to devise will indicate any impurity. It is well known that sulphur exists in two main modifications; one of them is the form in which it is deposited by the electrolysis of sulphides, the other by the electrolysis of its chloride or bromide. This important observation we owe to Berthellot.' I considered it of the first importance to examine the relations of these two forms of sulphur, and to make a very long story short I found that one modification certainly and the other probably, refuses to conduct electricity at all. On the other hand a mixture of these substances conducts, not well, but distinctly, and the evidence, so far as it goes, tends to show that the conduction is electrolytic in a sort of way—for it is accompanied by the phenomenon of electric absorption, which is most satisfactorily explained on the whole by a sort of electrolysis. There are a large number of subsidiary phenomena also tending to support this view. We are then in this position. The two sorts of sulphur insulate separately but conduct when mixed, that is they combine, for the mixture has different properties from either of its constituents. If this is granted, what is there to prevent us from assigning to each of the two modifications something of an elemental character? Similar results have been attained by totally distinct means by chemists working on the metals of the rare earths and on Beryllium. Is it possible that the idea of an absolutely hard and fast element may have to give way, and that we shall have to

modify our views as to elements by "correcting terms"? Long ago, Faraday drew attention to the supposed absolute similarity of molecules in the phrase that they behave like "manufactured articles." This phrase has been worn rather bare in the course of its use in theological argument, and was long ago shown by Clifford to be a statement going beyond what is known of the facts. In the case of sulphur, so far from the molecules being almost identical, they have no more than a family likeness, and form groups with properties gradually changing from the most stable amorphous variety on the one hand, to the quite stable crystalline variety on the other. I am persuaded that the high and dry view of the absolute similarity of molecules as roughly taught in text books has done much harm as well as good, and the science of chemistry is now sufficiently advanced to allow the more correct view to be habitually used without disadvantage. One consequence of the chemical theory of electricity—we will not quarrel as to the name, though, as a matter of fact, there must be a new science lying equally behind both electricity and chemistry—is that the possibility of charge without the intervention of free atoms cannot be admitted. It was for this reason that in 1889 I suggested a purely chemical theory of the action of the ordinary frictional machine, in which I postulated the decomposition of glass or water or both as a consequence of mechanical friction. The idea was new to me at the time, but it has probably been advanced before. At that time I had made a few experiments on the change of composition produced by pressure on complex substances, with the result that the majority of the substances I examined had their melting points changed when pressed with as high a pressure intensity as soft steel will bear.

Since then I have made a good many more experiments which I have not published hitherto, as they were perhaps too informal and intermittent, but the general result has been with some exceptions the same. Since then Mr. Carey Lea, in America, has succeeded in decomposing substances by rubbing them in a mortar, and that in at least one case where rise of temperature

would not account for the result. Consequently, the chemical theory of the frictional machine may be said to be placed on a sound basis. At the same time it is only fair to say that Mr. Lea's experiments have not yet been confirmed. A year ago I began to conduct a check series of experiments by another method, but I have not had time to carry them through.

I ought perhaps to have curtailed my remarks on my own work rather more, but I wished to show that problems of the very first importance are to be approached in the domain of physical chemistry, and I naturally took that part of the subject with which I am best acquainted, to form a basis for my remarks.

A Contribution to the CHEMISTRY of AUSTRALIAN MYRTACEOUS KINOS.

By J. H. Maiden, F.L.S., &c., and Henry G. Smith.

[*Read before the Royal Society of N. S. Wales, June 5, 1895.*]

In the investigations that have been carried out at the Technological Museum during the last few years, on the exudations of the Australian Myrtaceæ, it has been found that these substances known as kinos fall into three classes, which have been respectively named the Ruby, Gummy, and Turbid groups. The members of the first of these are soluble both in alcohol and water, giving a ruby coloured solution, those of the second are practically insoluble in alcohol, and the third, when treated with hot water and allowed to cool, contain a body or bodies which render the liquid turbid.

We now deal with kinos belonging to this last group, the present investigation having been carried out with the view to identify the substances causing the turbidity already referred to.

In the papers already published* it was suggested that this body was catechin for the following reasons—it was mostly dissolved in boiling water but separated again on cooling, it gave an intense purple colour with concentrated sulphuric acid (in the precipitate of the Eucalyptus kino tested), it gave a yellow colour with caustic potash; for these reasons, which are admittedly inconclusive, the substance was at the time considered to be catechin. Work on these kinos has been since proceeded with, though slowly, in consequence of other demands on our time.

At the recent meeting (January 1895) of the Australasian Association for the Advancement of Science, held at Brisbane, Dr. Lauterer of that city, read a paper on "Queensland native astringent medicines," and the paper has since been published.† The most interesting observation in this paper from a scientific stand point is where the writer seeks to show that the substance causing turbidity in kinos is ellagic acid. As the presence of ellagic acid had not been detected by us in kinos, we considered that the time had arrived when the results of our experiments in this connection might be usefully published. It is with pleasure that we place the results of our investigation before this Society, and announce the separation of two new organic substances, to the presence of which, either singly or in company, the turbidity of some kinos is due.

As the work of classification has already been dealt with by one of us, in three papers read before the Linnean Society of New South Wales,‡ we have restricted our researches to a typical Eucalyptus kino belonging to the turbid group, namely that of *Eucalyptus hemiphloia*, F.v.M., and also that of *Angophora lanceolata*, Cav.§

---

* *Proc. Linnean Society, N.S.W.*, [2] VI., 389 (1891).

† Chemist and Druggist of Australasia, May 1st, 1895, p. 168.

‡ *Proc. Linn. Soc.*, [2] IV. 605-18 (1889); [2] IV. 1277-87 (1889); [2] VI. 389 (1891).

§ The exudations of the *Angophoras* closely resemble those of some members of the Turbid Group of Eucalyptus kinos. See "Angophora Kino."—***Proc. Linn. Soc., N.S.W.*** [2] IV. 253 (1891.)

Eudesmin ($C_{26}H_{30}O_6$)

We give this name* to one of the substances causing the turbidity of solutions of kinos of the turbid group, and proceed to give an account of the method adopted for its isolation, prior to dealing with its properties and composition.

It is not necessary to enumerate the many methods adopted to isolate this substance. We will at once proceed to describe what we at present believe to be the best method for its extraction, and by this process it can be easily obtained crystallized, and in a pure state.

When the kino is finely powdered and treated with ether in a dry state, practically nothing is taken into solution, but if a small quantity of water is added to the fine powder and gently heated, a thick paste is formed. If on cooling, this paste be transferred to a separator, ether added and well agitated, it partially goes into solution, the ether presenting a yellow colour. By repeated agitation, removal of the ethereal layer, addition of fresh ether, and repetition of the process for about two days, the greater portion of the substances soluble in ether are removed, no emulsion being formed. The ether used in these successive extractions is mixed, distilled off at a low temperature, and the residual mass, partly resinous looking and partly crystalline, is digested in absolute alcohol, (in which it is readily soluble with the aid of heat), transferred to a beaker and allowed to cool. If only a very small quantity of the alcohol has been added, nearly the whole of the "Eudesmin" will crystallize out; these crystals can be transferred to a filter, washed with rather dilute alcohol to remove the amorphous resinous looking body, and transferred to a porous substance to drain. Recrystallization is all that is now needed to obtain these crystals in a perfectly pure state. The appearance of the body as thus obtained is that of a pure white mass with a

* The name Eucalyptin being preoccupied, we accepted the suggestion of our colleague Mr. R. T. Baker, of the name Eudesmin, from *Eudesmia*, Robert Brown's name for the genus which he subsequently ascertained was identical with L'Heritier's *Eucalyptus*.

lustre resembling spermaceti. It is necessary that the successive filtrates obtained from these crystals be placed in a vessel to allow of the slow evaporation of the alcohol, so that the remaining crystals of eudesmin may form and so be removed, or the filtrates may be evaporated to dryness, and again treated with absolute alcohol with the aid of a gentle heat, and the previous process repeated. If care is taken in the manipulation, it is possible to almost entirely remove eudesmin from these solutions, and so separate it from the resinous looking body, which is readily soluble in even dilute alcohol. A special reason why it is necessary to endeavour to obtain this substance as free as possible from eudesmin will appear presently.

Eudesmin has been found in the kino of *Eucalyptus hemiphloia* F.v.M., (a typical turbid kino); in what other kinos it is contained will form the subject of a separate investigation. The kino of *E. hemiphloia* used in these investigations was all obtained from one tree.

Physical Properties and Reactions of Eudesmin.

The crystals which are however obtained by slowly evaporating an alcoholic solution are rhombic prisms; larger crystals are obtained by slow crystallization from amyl alcohol; these crystals extinguish parallel to the principal axis and polarize at times in bright colours. They show faces of the right rhombic prism with brachypinakoids. The termination planes are mostly macrodomes, pyramidal faces not having yet been detected. The formula therefore is—

$$(\infty P + \infty \breve{P} \infty + \overline{P} \infty)$$

Eudesmin is soluble in hot water but crystallizes out again on cooling, it possessing but the slightest solubility in cold water. It melts on the surface of mercury at 99° C. (result of several determinations). As it melts below the boiling point of water, care must be taken not to raise the temperature too rapidly or too high when determining its solubility in water, as it fuses into globular masses as 100° C. is approached.

It is soluble in cold alcohol (not too dilute), readily on warming; also in amyl alcohol, ether, acetic ether, chloroform, but not in benzole, petroleum spirit, or bisulphide of carbon. It is neutral when in solution in either water or alcohol.

Eudesmin when obtained from absolute alcohol is anhydrous, (whether one or more molecules of water are found in crystals otherwise obtained has not yet been ascertained). When fused at 100° C. and allowed to cool, no loss of weight takes place. It melts into a whitish resinous looking mass partly transparent. When ignited it readily burns with a very smoky flame.

When eudesmin is dissolved in hot alcohol, water added until the slightest precipitate appears to form, and the solution left to stand for some hours, beautiful acicular crystals are obtained, having a length, in some cases, of nearly half an inch.

Eudesmin is soluble in concentrated sulphuric acid with a dark colour; after a few minutes the edges of the drop of acid become purple, and in about half an hour the whole acid in the watch glass becomes of a beautiful purple colour; after some time the colour fades and a dark precipitate separates, this is also the case when water is added to the purple liquid.

Eudesmin is soluble in strong nitric acid with a beautiful yellow colour; after a time dendritic forms make their appearance, and continue to increase until the alteration is completed; these are light yellow and insoluble in water. These two reactions with H_2SO_4 and HNO_3 appear to be characteristic.

Eudesmin dissolves with explosive violence in fuming nitric acid, forming a yellow liquid after the lapse of a minute, and with the same insoluble alteration-product as obtained with strong nitric acid. It is to these alteration and decomposition products that we must eventually look, to determine the molecular constitution of eudesmin.

Eudesmin is but slightly soluble in aqueous or alcoholic potash in the cold or on warming.

Eudesmin is soluble in glacial acetic acid, but separates on the addition of water.

Eudesmin is odourless and almost tasteless, being very slightly sweetish.

Chemical Composition.

Two combustions were made, the results obtained being practically the same in both cases, as will be seen from the following figures:

No. 1. ·2253 gram gave ·1338 H_2O and ·5464 CO_2

or	66·142	per cent. carbon
	6·598	„ hydrogen
	27·260	„ oxygen
	100·000	

No. 2. ·2494 gram gave ·1447 H_2O and ·6060 CO_2

or	66·268	per cent. carbon
	6·447	„ hydrogen
	27·285	„ oxygen
	100·000	

Mean of the two combustions:—

	66·2050	per cent. carbon
	6·5225	„ hydrogen
	27·2725	„ oxygen
	100·0000	

From which we may deduce the formula $C_{26}H_{30}O_8$

The peentage composition of a compound having the above formula is

	66·383	per cent. carbon
	6·383	„ hydrogen
	27·234	„ oxygen
	100·000	

As this shows a loss of less than two-tenths per cent in the carbon, and less than one and a-half tenths per cent. excess in the hydrogen, on the mean of the two combustions, and as these differences are allowable, and in correct order as errors of experiment, we may consider $C_{26}H_{30}O_8$ as the correct empirical formula. The molecular formula is a matter for future consideration, when decomposition products of a satisfactory nature shall have been obtained.

Do "Turbid" Kinos contain Ellagic Acid?

As eudesmin is soluble in hot water and but slightly in cold water, this property of course indicates that it assists to give turbidity to aqueous solutions of kinos, but the large proportion of a resinous looking body extracted by ether, and left on removal of eudesmin, points to the fact that eudesmin is not the only substance that causes this turbidity.

As before mentioned, it has been stated emphatically that the substance causing this turbidity is ellagic acid. We will submit that ellagic acid is not present in either the kino of *Eucalyptus hemiphloia* or in that of *Angophora lanceolata*, (the only two turbid kinos exhaustively examined). The ready solubility in boiling water of the precipitated substances on cooling from a hot aqueous solution of the kino, by itself tends to indicate that the substance cannot be ellagic acid, as this acid is practically insoluble in water even on boiling.* Its ready solubility in alcohol also tends to indicate that it is not ellagic acid. As the precipitated powder causing the turbidity when the kino of *Angophora lanceolata* is treated with water, has been particularly mentioned as consisting of almost pure ellagic acid, and as the kino of *Angophora lanceolata* does not appear to contain eudesmin, a portion of the above precipitated powder (from cold water) was taken and decomposed by fusing with potash. The products of decomposition were found to be protocatechuic acid and acetic acid; these

* Vide *Watt's Dictionary of Chemistry*, (Morley & Muir) Vol. II., page 430, where the properties of ellagic acid are given as "minute yellowish prisms, insol. water and ether, sl. sol. alcohol," &c.

decomposition products at once point to the fact that the powder was not ellagic acid.

The protocatechuic acid is readily obtained in a crystalline state by removing the volatile acids from the acidified solution (using H_2SO_4) by petroleum spirit, and then agitating with ether. An aqueous solution of these crystals gives the reactions for protocatechuic acid in a most satisfactory manner.

We subjoin a tabular statement of the reactions obtained with ellagic acid freshly prepared from "Divi Divi" (pods of *Cæsalpinia coriaria*), and with the precipitate from *Angophora lanceolata*, prepared exactly in the same way, namely, by concentrating a solution of the material in alcohol, pouring into water, filtering, washing, dissolving in alcohol, again filtering and evaporating to dryness.

Ellagic Acid from Divi Divi.	Reputed Ellagic Acid from *Angophora lancolata*.
Strong HNO_3 dissolves with reddish to crimson colour; on adding H_2O light yellow is produced.	Strong HNO_3 slightly dissolves forming a light yellowish colour.
Fuming HNO_3 dissolves, forming a red colour not so crimson as preceding.	Fuming HNO_3 dissolves, forming a dark reddish brown colour; on adding H_2O a yellowish resinous looking body separates.
KHO dissolves dark yellow.	The same.
H_2SO_4 dissolves instantly to a beautiful purple, becoming purplish-black on standing.	H_2SO_4 dissolves instantly forming a yellow colour, which becomes dark brown on standing.
Boiled with H_2O very little dissolves; the solution when treated with Fe_2Cl_6 gives a purple colour changing to blackish (ink).	Boiled with H_2O dissolves entirely, ppt. again on cooling; when heated with Fe_2Cl_6 dirty green colour and dirty green ppt. are formed.
The dried powder placed in Fe_2Cl_6 solution, soon becomes bluish-black, on standing becomes more black.	The dried powder placed in Fe_2Cl_6 solution becomes greenish-brown, becoming greener on standing.
When a solution in alcohol is evaporated a crystalline deposit is formed, easily seen under the microscope.	Solution in alcohol dries mostly as an amorphous varnish or dull powder not crystalline, as seen under the microscope.

As ellagic acid has as yet only been detected in substances which give *pyrogallol* on decomposition, the substances (tannates)

obtained by precipitating the aqueous solution of *Eucalyptus hemiphloia* kino, (from which the bodies soluble in ether had been removed) with neutral acetate of lead, and also that obtained by adding basic acetate of lead to the filtrate from the first precipitate, (which precipitates substances not thrown down by the neutral salt), were taken. The lead from these precipitates was removed by sulphuretted hydrogen and the filtrates evaporated to dryness. By heating these two tannins in glycerine for half an hour at 200° C. the decomposition product was in both cases *catechol* and not *pyrogallol*, and a yellowish resinous looking body, difficultly soluble in cold water, but soluble in boiling water, was also removed by the ether at the same time.

This reaction shows that the tannic acid was not one likely to give ellagic acid as a decomposition product. When portions of these same tannins were heated in a closed tube for one hour at 100° C. with dilute hydrochloric acid, a body in appearance allied to one of the red decomposition products known as kino red, elm red, hemlock red, &c., &c., is obtained as a product of decomposition. From these results, although we might be inclined to look for two tannic acids, yet from the products of decomposition we must conclude that there is but one tannic acid in the kino of *Eucalyptus hemiphloia*.

As the whole of the tannin of *Angophora lanceolata* is precipitated by neutral acetate of lead, we may infer the same also of this kino, the decomposition products of the tannin obtained from the lead precipitate being *catechol* when decomposed by heating at 200° C. for half an hour, and protocatechuic acid and acetic acid when decomposed by fusing with potash. The reactions for the protocatechuic acid obtained from this tannin are most clear and distinct, no other product appearing to be present to interfere.

From the decomposition products of the tannins from *Eucalyptus hemiphloia* kino and from *Angophora lanceolata* kino, we consider that these tannins are identical.

The Second Body Isolated from the Kino of *Eucalyptus hemiphloia*, F.v.M.

As already stated, there is a resinous looking substance extracted with eudesmin by ether from the kino of *E. hemiphloia*. As this is soluble in boiling water (with difficulty, as it melts into greasy looking masses), but separates again on cooling, we must consider that this substance also plays a part in the turbidity of this kino as well as eudesmin. This body, when allowed to precipitate from boiling water is removed from the aqueous solution by agitating with ether, the liquid becoming quite clear, demonstrating tnat the whole of the bodies causing this turbidity have been removed. As the ether slowly evaporates, crystals form at the junction of the ether and water; these fall through the liquid to the bottom of the vessel, either by themselves or when the vessel is gently agitated. We have only just succeeded in crystallizing this substance, and a subsequent communication will be made to the Society when its chemistry has been worked out.

As seen under the microscope the crystals are plates. In the early state of crystallization the rhombus is the principal form, but as they become larger they form six sided plates. These polarize most beautifully in bright colours.

One determination was made of the melting point, it was found that the crystals melted on the surface of mercury at 162° C.

Its colour reactions are as follows, and from the results at present obtained it appears that the characteristic colour reaction previously given to ellagic acid, of forming a crimson colour with fuming nitric acid, will have to be modified, as the body of which we now write, gives this crimson reaction most beautifully clear and pure, not only with fuming nitric acid, but with nitric acid, and also when the nitric acid is slightly diluted.

KHO gives a bright yellow colour, which colour is permanent in the air even until it is dried up. Sulphuric acid dissolves it yellow, becoming brown on standing. Fe_2Cl_6 solution has but little colour reaction with these crystals.

It crystallizes from boiling water in plates. Ether dissolves it, although not readily; the ethereal solution dries into an almost amorphous substance. Alcohol dissolves it easily.

The distinctive colour reactions given by eudesmin and this body serve at once to distinguish them in the absence of any determinations of crystalline form. We have provisionally named this substance *Aromadendrin*.

The chemistry of the substance causing the turbidity in the kino of *Angophora lanceolata* will form the subject of a later communication. We have succeeded in isolating a few well developed crystals of the body, after numerous failures, and hope now to be successful in crystallizing it readily for purposes of investigation.

PAPER ON AERONAUTICAL WORK.

By Lawrence Hargrave.

[With Plates I.–IX.]

[*Read before the Royal Society of N. S. Wales, June 5, 1895.*]

The paper read before this Society, Vol. xxvii., p. 75, on Flying Machine Motors and Cellular Kites concluded with some remarks about a motor that was exhibited on that occasion. The motor was No. 21, and *Plates* 1, 2, 3, show three views of it. The weights are remarkably low, but the thrust chronograms made by the apparatus show that to attempt a free flight with No. 21 would be to court disaster.

The burners and spirit holders that have been tried fail to produce uniform results. The fault is now thought to be in the method of discharging the spirit vapour into the mixing chamber. The amount of the vapour depends on the heat under the holder, and this again on the amount of air that is admitted to the mix-

ing chamber, which is determined by the pressure in the holder causing the induced current of air for combustion. This cycle of events is readily disarranged. The cure that suggests itself is to make the holder of large capacity, and charge it with about one of spirit and four of compressed air by volume, placing a cock between the holder and the discharging orifice. The vaporising must be effected between the orifice and the cock, preferably by means of a few turns of the pipe at the point where the mixed air and spirit vapour begins to burn. That is, on the principle of the Wells, Doty, Denny, or Moeller and Coudrup lights and burners.

The twin-screws and gear weigh 3·75 ounces, which is the same as the single screw, shaft, and crank shaft coupling. The best results have been produced by the single screw. The screws have flat blades and the pitch is varied by twisting them in the tin sleeve that represents the boss. The long blade and fine pitch is thought to be most effective ; but this may not be true, as the back pressure on the pistons prevents a high piston speed being attained.

A weight driven thrust measuring and recording apparatus for comparing the screws was tried and showed, amongst other things, that the effective pressure on the pistons, necessary to produce ·64 pounds of thrust and 340 revolutions per minute, was only 10·9 pounds per square inch.

The lubricator is unscrewed, partly filled with oil, and replaced before each trial. Live steam condenses in the lubricator, and the oil overflows into the valve cover and thence through the engine.

The valve in the first instance was made of brass : it used to cut up the cylinder face and valve cover. The steel valve now in position works satisfactorily. A spring was on the back of the valve cover and made it in effect a safety valve. The spring has been removed, and the bridge now holds the valve cover by two hooks to the steam pipe of the top cylinder and the post that supports the engine on the top of the water tank.

The feed pump is the exact thing required. There is a pestle-shaped knob on the lower end of the pump rod. This works in a cup at the bottom of the hollow pump ram. The ram is held against the pump rod by two springs. When the fire is fairly lighted and the pump crank on the top centre, the ram can be worked by hand till the engine starts.

The following table shows the approximate capabilities of No. 21 motor. The revolutions are only recorded when the engine causes sufficient vibration to give a tremor to the pen of the chronograph.

Results of some of the Trials of No. 21 Motor.

Number of Chronogram.	Cubic inches of Spirit burnt.	Cubic inches of Water pumped.	Time of Run in Seconds.	Maximum Thrust in Pounds.	Screw Propellers.	Pitch Angle.	Revolutions per minute for part of the run.
2	1·73	10·81	80	·4	Twin screws	39°	
3	1·73	7·35	95	·5	Twin screws	30°	
4	2·6	11·245	128	·5	Twin screws	30°	
5	2·6	11·245	107	·75	Single screw, 31″ diam.	30°	
6	2·6	11·687	100	·625	Single screw, 31″ diam.	30°	
7	2·6	13·84	145	1·0	Single screw, 31″ diam.	30°	300
8	2·6	15·57	130	·64	Single screw, 27″ diam.	39°	329
10	2·6	12·54	85	·7	Single screw, 34″ diam.	36°	300
11	2·6	9·08	66	1·5	Single screw, 34″ diam.	30°	
12	2·6	14·4	106	·75	Single screw, 34″ diam.	30°	304

The experiments are now being carried out at Stanwell Park, situated about thirty-two miles south of Sydney. This somewhat isolated locality is favourable for kite flying when the wind is from the eastward, between S.S.E. and E.N.E. In spite of unavoidable delay and interruptions some progress has been made. The kites are expected to provide a handy means of lifting the experimenter and flying machine from the ground, and to afford a safe and easy descent.

The cellular kite is the germ that has been modified and developed, and in all probability it will prove to be the permanent

type of the supporting surfaces of flying machines. A single experiment will show anyone that absolute stability and certainty of action may be relied on ; and that the careful adjustment and balancing of single planes and affairs with a diedral angle is wasted labour.

The earlier forms of cellular kites had the planes altogether edged with wood, and they needed much diagonal staying. Pin and eye joints would have been necessary at all the corners if they had been made to collapse, and want of space for storage began to be felt. The distance between the cells has been greatly reduced ; the exact distance that they can be apart without impairing the efficiency of the after cell is not known ; but, as far as stability is concerned, a single cell is in stable equilibrium. There is a single celled kite in the collection, measuring two feet six inches long, two feet six inches deep, and six feet wide, and it flies quite steadily.

A number of experiments have been made with curved wooden cellular kites. Efforts have been made to induce them to soar to windward of the peg to which the string was fastened. *Plate* 6 shows the nearest approach to soaring that has been attained. There is a wedge and screw that secures the forward cell at an angle with the stick and tail cell, so that various degrees of tilt may be tried.

Plates 4 and 5 show a variety of stable forms of kites. Some are probably new and may be useful to the readers of this Journal.

A great deal has appeared about Mr. Otto Lilienthal's long jumps from an eminence on an apparatus weighing about forty-four pounds, and spreading one hundred and fifty square feet of wing surface. The weight seems very high for a structure intended for aeronautical purposes, but doubtless it is skilfully designed and the material found to be requisite. The writer put together and made several jumps with a trussed affair having four wings eight feet by four feet nine inches, equal to a total area of one hundred and fifty-two square feet of arched surface ; it weighed under

twenty-five pounds. This line of experiment was discontinued as it was seen that an accident might readily occur without making any real progress with the flying machine.

The three decked type of cellular kite has disappeared, *Plate 7* being probably the last that will be made. This was the first kite that any attempt to raise the experimenter was made with. A screen fifteen feet by eight feet was erected on the sea beach. It was thought that a comparative calm would exist behind the screen; this proved fallacious, the eddies being more embarrassing than the unchecked wind, which was blowing at 20·1 miles per hour. However, the kite was expanded, and when the screen was lowered the upper deck collapsed, and with it of course the rest of the booms.

The second attempt at making an ascent was also a failure, caused by one of the booms of A, the highest kite, (see *Plate 9*) bending and breaking. The booms were not pinned at the crossing as they should have been. The kite of course fell and damaged B, the one underneath. This left only C and E, having a total surface of one hundred and fifty-nine square feet undamaged; and as the wind was 16·5 miles per hour no ascent could be made on that day.

Plate 8 shows kite D with all details. This is the last two celled folding kite constructed, and of course contains all the improvements that experience has shown to be necessary. The shoes A slide along the top and bottom members of the main frame towards D: this allows the corners to come inwards, and the kite to fold to eight feet six inches, by 2 feet 3·75 inches, with a thickness of about 1·5 inches. The nails at the crossing of the booms need not be removed when furling, in fact they facilitate packing and prevent the booms getting mixed. When the kite is furled the main frame has no strength to stiffen it against winding; but when the corners are boomed out the whole kite is practically a rigid structure. It is not clear why the stretched surfaces stiffen the main frame, but they do so nevertheless. The

surfaces are made of very inferior calico. The timber parts are of American red wood.

For the third trial the five kites tabulated on *Plate* 9 were taken to the beach. A, B and C were flown on forty-three fathoms of log line, which they broke. C was dragged through a lagoon and B caught on the branch of a dead tree. B was released undamaged; and, with assistance, A and B were dragged back to the anchorage; the moorings consisting of a sack of sand close to the sea.

A stronger line was bent on to B; and then D and E were flown, the sling seat being attached below E. The strain on the line was about eighty pounds, and the distance of E from the ground, eight or nine feet.. The line was then slacked away to forty-two feet, when the pull reached a maximum of one hundred and sixty pounds.

The velocity of the wind on the beach was 16·8 miles per hour, and falling lighter; so that the result of the third trial was that two hundred and thirty-two square feet of kites pulled two hundred and three pounds: that is, one hundred and sixty pounds on the spring balance plus forty-three pounds weight of gear aloft: the slope of the kite line being about 65° with the horizon. The velocity of the wind on the beach, might be, and most probably was, very much less than at A or even at E.

The distances between the kites were A to B, ninety-six feet; B to D, seventy-eight feet; D to E, eighty-four feet.

After a tedious delay, waiting for a suitable wind, the fourth trial took place on November 12th. The five kites were the same used on the last occasion, with the exception that the wires used for the chords of the bending battens had been removed. *Plate* 7 shows the method of curving the surfaces on the supposition that more lift is obtained thereby, which is very doubtful with a calico surface.

After A, B, C and E had been successfully flown, a rather flimsy joint at the right hand lower corner of the forward cell of C gave

way, this necessitated hauling down E and C, and toggling on D in place of C. Two gentlemen assisted and it was safely accomplished. A, B, D and E were now flying, E being about six feet from the ground, the lot pulling one hundred and eighty pounds. E was secured by a guntackle purchase to the spring balance and the spring balance to two sacks of sand.

The sling seat was toggled on and the writer got aboard with a hand anemometer and a clinometer. James Swain, the assistant, slacked away the tackle fall to the end. The apparatus was then forty-two feet to leeward of the sand bags and veering with the wind round an arc of 40°. This was unexpected, as the wind was well to the eastward of S.S.E., and the coast trends N.N.E. and S.S.W. At this stage there were only a few pounds weight unsupported by the kites. The velocity of the wind was 14·7 miles per hour. The pull on the spring balance one hundred and twenty pounds, and the slope of E with the horizon was 15°.

In about a quarter of an hour the wind freshened and raised the experimenter, when he found the velocity of the wind to be 18·6 miles per hour, the spring balance reading one hundred and eighty pounds maximum. The wind falling lighter, kites and experimenter came down. Several more ascents were made, but not of sufficient duration to read the anemometer, which has a two minutes and glass. However, a long and strong puff eventually came and sent everything up like a shot. A careful reading showed the wind velocity to be twenty-one miles per hour, with two hundred and forty pounds maximum pull on the spring balance, the total weight aloft being two hundred and eight pounds five ounces. The angle at which A, B and D were flying above was measured from E to be about 60°, and also the height from the sling seat to the ground, sixteen feet. The upper kites and E were sloped to the horizon at about the same angle so that the forward ends of the cells were open to view from E.

On coming to the ground, the writer, whilst still on the sling seat, was just able by the aid of the guntackle purchase to haul himself and the kites to the moorings. The descent in every case

was of the gentlest description. D was the most difficult kite to haul down. The kite line used is common Manilla clothes line, and is not easy to handle when strained. A small winch on the sling seat will make an ascent possible without any assistance whatever.

From experiments previously made with the three cornered calico kite in *Plate* 4, it is gathered that an increase in the velocity of the wind on this occasion would have brought A, B and D nearer and nearer to the zenith, when a point would have been reached where the kites and line would begin to lean over sideways and come nearer to the ground, making a considerable azimuthal angle with the direction of the wind. Supposing the twenty-one mile wind to have a force of two pounds per square foot: then two hundred and thirty-two square feet of kite at 15° slope would exert a lift of two hundred and seventeen pounds and a drift of fifty-eight pounds. If the line were moved further forward so that the slope became 10°; an equal velocity of wind would only produce one hundred and fifty-three pounds of lift, and the drift would be reduced to twenty-seven pounds. So that, if the kites are merely to lift weight, the line might with advantage be moved aft. If the kites are to be driven by a motor on board the lowest one, the weight must be moved forward when the thrust of the motor exceeds the drift.

It is thought that this experiment marks an epoch in the series of aeronautical contrivances recorded in our Journal. Although the altitude attained was trifling, the conditions would be identical if the kites had been held by a mile of piano wire instead of the clothes line.

The particular steps gained are the demonstration that an extremely simple apparatus can be made, carried about, and flown by one man; and that a safe means of making an ascent with a flying machine, of trying the same without any risk of accident, and descending, is now at the service of any experimenter who wishes to use it.

NOTES ON TWO NEW MINERAL SUBSTANCES FROM THE AUSTRALIAN BROKEN HILL CONSOLS MINE.

By E. F. PITTMAN, A.R.S.M., Government Geologist, Sydney.

[*Read before the Royal Society of N. S. Wales, June 5, 1895*]

In November 1893, a new mineral named Willyamite from the Australian Broken Hill Consols Mine was described at a meeting of this Society, and the following notes relate to two new mineral substances, which are somewhat remarkable in their composition, and which are from the same interesting mine, having been forwarded to me by Mr. Geo. Smith, the General Manager. Although both these substances differ materially from anything hitherto described, neither of them is regarded as a distinct mineral species. They appear to be merely mineral mixtures and may be described as alteration products, the one having evidently been derived from the mineral dyscrasite and the other from argentiferous galena.

I.—The first substance was found at a depth of from one hundred to one hundred and forty feet (vertical) in a limonite gangue and was associated with stromeyerite, bindheimite, volgerite, and azurite. One specimen found by Mr. Smith was encasing a kernel of dyscrasite. The substance is massive, the colour is greyish-brown, but when a surface is cut and polished on a lapidary's wheel, or when a thin section is examined under the microscope it is seen to have a finely banded structure, the bands having a somewhat metallic lustre. The substance is sectile. The specific gravity of the specimen on the table is 4·9. Two analyses of the substance were made in the Geological Survey Laboratory, No. 1 being by Mr. J. C. H. Mingaye, F.C.S., and the other by Mr. Harold P. White, F.C.S.

	I.	II.
Moisture at 100° C. ...	·56	·13
Combined water	4·04	4·37
Silver	47·46	45·87
Antimony	16·87	20·72
Copper	·11	·48
Lead	·62	·31
Arsenic	trace	trace
Gold	trace	...
Lime (CaO)	3·78	4·25
Magnesia (MgO)	1·17	·20
Ferric Oxide (Fe_2O_3) ...	2·11	·45
Chlorine	13·69	12·27
Insoluble matter (gangue)...	1·01	·90
Oxygen (by difference) ...	8·58	10·05
	100·00	100·00

Mr. Mingaye added that the silver is present as chloride, and also in combination with antimony, as antimoniate (with possibly some antimonite) of silver. The lime, copper, lead and magnesia are also probably present as antimoniates.

The analyses taken in conjunction with the somewhat banded appearance which polished sections of the substance presented, pointed to the probability of its being a mixture and not a mineral of definite chemical composition, and with the object of settling the question it was suggested to Mr. Mingaye that he should digest some of the finely powdered mineral with strong ammonia. This was done with the result that practically the whole of the chloride of silver was dissolved, only a trace remaining at the end of forty-eight hours.

An analysis by Mr. Mingaye of the residue insoluble in ammonia yielded as follows :—

Silver	19·71
Gold	trace

Mo. Bot. Garden,

Antimony	35·12	
Arsenic	trace	
Lead...	2·79	
Copper	·52	
Iron	5·18	
Calcium	4·84	
Magnesium	·17	
Insoluble matter (gangue)...	5·20	
Chlorine	·14	
Water	6·01	mean of two experiments by direct weighing.
Oxygen	19·69	
	99·37	

At the suggestion of Professor Liversidge a polished surface of the substance was then etched by allowing a solution of strong ammonia to stand on it for some hours. The result clearly shows that the chloride of silver has been removed leaving the antimoniate of silver in relief.

II.—The second substance is clearly an alteration product derived from argentiferous galena. It is dark grey in colour—has a cubical structure, being in fact pseudomorphous after galena. It is sectile—has a variable specific gravity—that of the specimen on the table being 6·38. Its chemical composition is chiefly sulphate of lead and sulphide of silver in widely varying proportions, with small quantities of sulphide of iron, sulphide of copper and sulphide of lead.

Altogether four analyses of this interesting substance have been made in the Geological Survey Laboratory, Nos. I., II., and III. being by Mr. J. C. H. Mingaye, and No. IV., by Mr. Harold P. White.

		I.	II.	III.	IV.
	Moisture ...	·08	Sb_2S_3 ·44	Moisture ·14	Fe_2O_3 ·3
Ag_2S	Sulphide of Silver	77·99	76·62	13·25	10·86
Cu_2S	„ Copper	·62	·32	1·82	2·00

		I.	II.	III.	IV.
FeS_2	Sulphide of Iron	1·42	·45	·42	
$PbSO_4$	Sulphate of Lead	19·36	19·80	77·60	84·61
PbS	Sulphide of Lead	...	·50	2·20	·96
	Insoluble matter	·30	1·60	4·50	1·00
		99·77	99·73	99·93	99·93

It will be seen from these analyses that the composition of the substance is too variable to allow of its being classed as a mineral species. A polished surface of the substance was treated for some hours with a solution of acetate of ammonia with the result that some of the sulphate of lead has been removed, leaving the sulphide of silver in relief.

The CUBIC PARABOLA as applied to the EASING of CIRCULAR CURVES on RAILWAY LINES.

By C. J. Merfield.

(Communicated by Mr. G. H. Knibbs.)

[With Plate X.]

Read before the Royal Society of N. S. Wales, June 5, 1895.

The cubic parabola having been adopted by engineers and surveyors of this Colony, as an easing curve to the circular arcs on railway and tram lines, exact and extended tables will be required. The following investigation and tables are intended to supply this want. Many of the methods that have been published are defective, and unsuited to the requirements of the engineer.

The use of the cubic parabola, as a transition or easing curve, is by no means new. The American and Continental Railways are mostly so located, that a curve of varying radius may be

applied to the circular arcs. The advantage of such a system cannot be overestimated. It is however not the object of this paper to discuss these matters.

Mr. Shellshear in his paper read before this Society, has given nearly all that can be desired about this particular curve, and his method of location is carried to a fair degree of approximation. For transitions of from one to two chains in length, his procedure is practically exact, provided that the radius of curvature be large at the point of contact with the circular arc. Increasing the transition to say four chains, the error becomes noticeable, and seems to require a more exact method of location.

In the following pages the necessary equations are deduced, which upon solution, will give data for the location of the cubic parabola to any circular arc, so that the radius of curvature will be equal to that of the circular arc at the point of contact. Table No. 1 gives the offsets, and other quantities, according to this exact method, in several useful cases.

This degree of accuracy may not always be required, it depends upon the solution of an awkward equation, which would perhaps deter some engineers from employing the formulæ.

During the author's duties in the Railway Construction Branch Public Works, N.S.W., he was called upon to prepare tables of the offsets to this curve, for several cases, to be used by the surveyors of the department.

The method adopted in their preparation, was to compute the offset, at the point of contact, from the equation $y_c = \frac{1}{3}\left\{ R - \sqrt{R^2 - \left(\frac{x_c}{2}\right)^2} \right\}$ the intermediate offsets being varied as the cube of the distance along the axis of X. This would represent a cubic parabola, but the radius of curvature is in error, to a small extent, at the point of contact with the circular arc. This error is however not sufficiently large to injuriously affect the usefulness of this approximate method.

To many the method of locating curves by a system of offsets is tedious. Tables of the angles, contained between the radius

vector and the axis of X, for every ten links from the origin along the curve, have been computed. Other useful data are added. Table No. 3 contains these quantities, computed by the exact method.

Table No. 4 is similar to the above, and corresponds to the parabola given by the offets tabulated in Table No. 2. The values of log "m" for various cases are given in Table No. 5.

The deduced formulæ will not only be found useful in the preparation of tables, but will be advantageous in many of the problems that beset the engineer or surveyor, in the location of this curve. For this purpose the equations are collated, so that a selection may be made for particular cases.

Notation.

ρ = Radius of curvature at any point.
R = Radius of circle = ρ at point of contact C.
x = Values along axis of X.
y = Values along axis of Y.
x_c = Value of x at point of contact C.
y_c = Value of y at point of contact C.
O = Origin of curve.
$K = c$ = Constant.
x' = Length $T\,K = E\,B$.
y' = Length $C\,K$. (See fig. 1)
H = Distance of parallel tangent.
ϕ = Angle contained between the tangent to the curve, and the axis of $X = C\,D\,B$. (Fig. 1)
θ = Angle contained between the radius vector and the axis of X.
θ' = Particular value of θ.
s = Length of cubic parabola $= O\,C$.
s' = Any length along curve.
ω = Angle $O\,L\,O'$. (See fig. 2.)
A = Area contained between x, y, and the curve.
θ_1 = Angle $O\,C\,B$. g = Gauge.
$x_1 = O\,E = x_c - x'$. v = Velocity.

Where differential or integral calculus is employed the usual notation.

The Cubic Parabola.

To overcome a train's centrifugal force, the outer rail of all railway curves should be elevated. Every change of curvature should have a corresponding alteration in the cant of the rails. As this alteration can be made only gradually, changes of curvature should be gradual. The cubic parabola, owing to its easy application, seems to be especially suited for this purpose. In the following pages, data necessary for their location are deduced.

Let the gradual superelevation of the outer rail be taken uniform, for distances from O along the axis X, or let $\frac{1}{e}$ be the rate of rise, then the rise at any distance x will be $\frac{x}{e}$. (See fig. 1)

If ρ be the radius of curvature at the corresponding point on the curve, we have the superelevation equal to

$$\frac{\text{gauge} \times \text{velocity}^2}{32{\cdot}17 \times \text{radius}},$$

the gauge being expressed in inches, the velocity in feet per second, and the radius in feet.

Therefore $\frac{g\,v^2}{32{\cdot}17\,\rho} = \frac{x}{e}$

$$\rho = \frac{g\,v^2 e}{32{\cdot}17\,x}.$$

Now for a given velocity and rate of rise $\frac{1}{e}$, the quantity $\frac{g\,v^2}{32{\cdot}17}$ becomes a constant, let it be represented by c.

Therefore $c = \frac{g\,v^2 e}{32{\cdot}17}$, and

$$\rho = \frac{c}{x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

But $\rho = \frac{\left\{1 + \left(\frac{d\,y}{d\,x}\right)^2\right\}^{\frac{3}{2}}}{\frac{d^2 y}{d\,x^2}} = \frac{d\,s^3}{d\,x\,d^2 y}$

Let us for simplicity take $d\,s = d\,x$ then we have

$$\rho = \frac{d\,x^3}{d\,x\,d^2 y} = \frac{d\,x^2}{d^2 y} = \frac{c}{x}$$

$$\frac{d^2 y}{d\,x^2} = \frac{x}{c}, \text{ integrating twice we obtain}$$

$$y = \frac{x^3}{6\,c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

This is an equation to the cubic parabola, which may be written

$$y = m\,x^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2'$$

in which $m = \frac{1}{6c}$ It is in this form that we will use the equation, to deduce the formulæ necessary for the location of the curve.

In the equation to the curve, the constant "m" may be fixed at pleasure, according to the requirements of the case. Now it is necessary that the radius of curvature at some point, shall be a particular value, so that we must give to the constant a numerical value, so that when placed in a particular equation, the desired result will be obtained.

The radius of curvature in any curve equals

$$\rho = \frac{\left\{1 + \left(\frac{dy}{dx}\right)^2\right\}^{\frac{3}{2}}}{\frac{d^2y}{dx^2}}$$

Cubic Parabola $y = m x^3$

$$\frac{dy}{dx} = 3 m x^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

$$\frac{d^2y}{dx^2} = 6 m x$$

Therefore $\rho = \frac{(1+9 m^2 x^4)^{\frac{3}{2}}}{6 m x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$

From this equation we may find m, if we know ρ and x, by a method of approximations, until the correct value is obtained. The method adopted is as follows :—

$$\tan \phi = \frac{dy}{dx} = 3 m x_c^2$$

Now $R = \rho = \frac{(1+9 m^2 x_c^4)^{\frac{3}{2}}}{6 m x_c} = \frac{x_c (1+\tan^2 \phi)^{\frac{3}{2}}}{2 \tan \phi}$

Reducing we obtain

$$\frac{x_c}{2R} = \text{Sin } \phi \text{ Cos}^2 \phi \ldots\ldots\ldots\ldots\ldots\ldots 5$$

A value of the angle ϕ, such that its sine multiplied by its cosine squared, will equal $\frac{x_c}{2R}$ can soon be found. If the tangent of this angle be placed in the equation

$$\tan \phi = 3 m x_c^2$$

we obtain the value of m required. (See table 5.)

Produce the arc $C\,C'$, which has the same radius as the curve at C, to the point T, until its tangent becomes parallel to the axis of X, (See fig. 1)

$$C\,B = y_c = m x_c^3$$

The co-ordinate y varies as the cube of the distance along the axis of X.

$$\text{Angle } \phi = C\ D\ B = C\ F\ G$$
$$\tan \phi = 3\ m\ x_c^2$$
$$x' = E\ B = R \text{ Sin } \phi$$
$$y' = G\ T = R - R \text{ Cos } \phi$$
$$H = T\ E = y_c - G\ T$$
$$E\ O = x_c - x'$$

The preceding investigation is an exact method of locating the cubic parabola, as applied to the easing of circular arcs.

Before explaining an approximate method, we will deduce some useful formulæ from the equation to the curve.

$$y = m\ x^3 \quad \ldots\ldots 2'$$
$$\tan \phi = \frac{d\,y}{d\,x} = 3\ m\ x_c^2 \quad \ldots\ldots 3$$

From equation 2', $m = \frac{y_c}{x_c^3}$; and by substituting this value of m in equation 3 we have

$$\tan \phi = \frac{3\,y_c}{x_c} \quad \ldots\ldots 6$$

Therefore the tangent at C, if produced to D, makes an angle with the axis of X, the tangent of which equals $\frac{3\,y_c}{x_c}$. Further than this we see from equation 6, that $D\ B = \frac{1}{3}\ x_c$, and $O\ D = \frac{2}{3} x_c$

Again $D\ C = y_c \text{ Cosec } \phi$

$$\text{Cot } \phi = \frac{x_c}{3\,y_c}$$

Therefore $D\ C = y_c \sqrt{1 + \frac{x_c^2}{9\,y_c^2}} = \frac{\sqrt{x_c^2 + 9\,y_c^2}}{3} \quad \ldots\ldots 7$

Let the angle contained between the radius vector, and the axis of X be denoted by θ.

$$\tan \theta = \frac{y}{x}$$
$$y = m\ x^3$$

Therefore $\tan \theta = m\ x^2 \quad \ldots\ldots 8$

The tangent of the angle varies as the square of the distance along the axis of X.

$$\tan \phi = 3\ m\ x^2 \quad \ldots\ldots 3$$

Comparing this last equation with number 8 we have

$$\tan\ \phi\ =\ 3\ \tan\ \theta.$$

$$x\ =\ \sqrt{\frac{\tan\ \theta}{m}}\ =\ \sqrt{\frac{\tan\ \phi}{3\ m}}$$

Length of Parabola

$$y\ =\ m\ x^3. \qquad m\ =\ \frac{y}{x^3}$$

$$\frac{d\ y}{d\ x}\ =\ 3\ m\ x^2$$

$$\frac{d\ s}{d\ x}\ =\ \sqrt{1+\left(\frac{d\ y}{d\ x}\right)^2}$$

Therefore $s\ =\ \int\ \sqrt{1+9\ m^2\ x^4}\ \ d\ x$

Expanding, and integrating the individual terms we find

$$s\ =\ x\ +\ \tfrac{9}{10}\ m^2\ x^5\ -\ \tfrac{9}{8}\ m^4\ x^9\ \text{etc}.....8^a$$

Remembering that $m\ =\ \frac{y}{x^3}$

we find

$$s\ =x+\ \tfrac{9}{10}\ \frac{y^2}{x}\ -\ \tfrac{9}{8}\ y^4\ .....9$$

Dividing both sides of equation by x we obtain

$$\frac{s}{x}=1+\ \tfrac{9}{10}\ \frac{y^2}{x^2}\ -\ \tfrac{9}{8}\ \frac{y^4}{x^4}$$

Remembering that $\tan\ \theta\ =\frac{y}{x}$, we have

$$s=x\ (1+\tfrac{9}{10}\ \tan^2\theta-\tfrac{9}{8}\ \tan^4\theta...).....10$$

The first two terms of any of the above expressions will give the length of the curve approximately. In the computation of the tables, the third term has been taken into account.

The area A contained between the co-ordinates, x, y and the curve is easily obtained.

$$\text{Area}\ A\ =\ \int y\ d\ x\ =\ \int m\ x^3\ d\ x$$

integrating, and remembering that $m\ =\ \frac{y}{x^3}$, we find that

$$A\ =\ \frac{x\ y}{4}\ .....11$$

The area therefore equals, one fourth x multiplied by y

Length of Circular Arc.

The length of circular arc $C\ C'$ is obtained in the following manner. (See fig 2.)

$$E\ B\ =\ G\ C\ =\ x'$$

$$\text{Sin}\ \phi\ =\ \frac{G\ C}{R}\ =\ \frac{x'}{R}$$

If the circular measure of the angle ϕ is now taken, and multiplied by the radius of the circular arc, we obtain the length of arc $T\,C$ or $T'\,C'$.

Now length of arc $T\,T'$ equals the circular measure of the angle ω multiplied by the radius. Hence the following formula

$$C\,C' = R\left\{\left[\omega - 2\,(\mathrm{Sin}^{-1}\,\tfrac{x'}{R})\right]\right\}\cdot 0002909 \ldots\ldots\ldots 12$$

The angle within brackets being expressed in minutes.

Approximate Method of Location.

We shall now proceed with the investigation of an approximate method.

$$\rho = \frac{c}{x} = \frac{1}{6\,m\,x} \ldots\ldots\ldots 1$$

Therefore $x = \frac{1}{6\,m\,\rho}$. $m = \frac{1}{6\,x\,\rho}$

In the preparation of the tables (excepting table 1*a* and 1*b*) x has been taken equal to four chains, this being the value adopted by the Railway Construction Department. But really x could be varied inversely as the radius. That is to say, if we use four chains as the length of transition to the ten chain radius arc, we would obtain the same result, by taking two chains as the length of easement to a twenty chain radius arc, providing the velocity is the same. However it is perhaps as well to keep x a constant value, and so avoid complexity.

To locate the position of the parabola. Let the circular arc $C\,C'$ be produced to T', where its tangent becomes parallel to the axis of X. Then the angle

$$C\,D\,B = C\,F\,T = \phi$$

Now $\tan\phi = \frac{C\,B}{D\,B} = \frac{d\,y}{d\,x} = 3\,m\,x_c^{\,2}$

$$y_c = m\,x_c^{\,3} \qquad m = \frac{y_c}{x_c^{\,3}}$$

Therefore $\tan\phi = \frac{3\,y_c}{x_c} \ldots\ldots\ldots 6$

The tangent at the point C, if produced to the axis of X, cuts it at D making $O\,D = \frac{2}{3}\,x_c$, and $D\,B = \frac{1}{3}\,x_c$. (See fig. 1)

Again $C\,G = E\,B = (R - G\,T)\,\tan\phi$

Approximately $E\,B = R\,\tan\phi$, taking $G\,T$ as a small quantity

Substitute for R the value $\frac{1}{6\ m\ x_c}$ 12

Also for tan ϕ the quantity $3\ m\ {x_c}^2$

Therefore $E\ B = \frac{3\ m\ {x_c}^2}{6\ m\ x_c} = \frac{x_c}{2}$ approximately.....13

From equation 13 we find that the point E at right angles to T, divides $O\ B$ into two equal parts nearly.

To find $T\ E = H$

$$T\ E = C\ B - G\ T$$

$$C\ B = y_c$$

and $G\ T = \frac{\left(\frac{x_c}{2}\right)^2}{2\ R}$ approximately, taking $G\ T$ as a small quantity

$$G\ T = \frac{{x_c}^2}{8\ R}$$

But $R = \frac{1}{6\ m\ x_c} = \frac{{x_c}^2}{6y}$

Therefore $G\ T = \frac{3}{4}\ y_c$ 14

$$T\ E = H = y_c - \frac{3}{4}\ y_c$$

Therefore $H = \frac{1}{4}\ y_c$ 15

Again $T\ E = K\ B = \frac{1}{4}\ C\ B$

$$K\ B = C\ B - C\ K$$

Therefore $K\ B = \frac{1}{3}\ C\ K$

Now $C\ K = R - \sqrt{R^2 - \left(\frac{x_c}{2}\right)^2}$

Therefore $C\ B = y_c = \frac{1}{3}\left\{R - \sqrt{R^2 - \left(\frac{x_c}{2}\right)^2}\right\}$ 16

This completes the approximate method of location. The length of the curve can be found by equation 9 or by 10.

Length of arc $C\ C'$ may be found from the equation number 11. If we take $E\ B = \frac{1}{2}$ this equation may be written

$$C\ C' = R\left\{\left[\pi - 2\ \mathrm{Sin}^{-1}\frac{x_c}{2\ R}\right)\right]\right\} \cdot 0002909 \text{.....17}$$

The radius of curvature may be obtained approximately by the following

$$\rho = \frac{1}{6\ m\ x}$$

substitute for m the value $\frac{y_c}{{x_c}^3}$, and we obtain

$$R = \frac{{x_c}^2}{6\ y_c} \text{.....18}$$

To find the exact radius of curvature in terms of x and y.

$$\rho = \frac{(1+9m^2x^4)^{\frac{3}{2}}}{6\,m\,x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

substitute for m its value $\frac{y_c}{{x_c}^3}$ and we obtain

$$\rho = R = \frac{\left(\frac{{x_c}^2+9\,{y_c}^2}{{x_c}^2}\right)^3}{\sqrt{36\,\frac{{y_c}^2}{{x_c}^4}}} = \frac{\sqrt{({x_c}^2+9\,{y_c}^2)^3}}{6\,x_c\,y_c} \ldots\ldots 19$$

To obtain ρ at any point on the curve, it is only necessary to place the values of the co-ordinates x and y in equation 19.

Tables.

Table 1 contains the data necessary for the location of the transition by the exact method. The first column gives the distance $x' = E\,B$, $E\,O = x - E\,B$. H equals the distance $T\,E$ of the parallel tangent, this quantity is to be set inwards, after the lines $O\,L$, $L\,O'$, have been fixed. This latter distance is obtained in the following manner

$$L\,E = L\,E' = \tan\frac{\omega}{2}\,(R+H)$$

$$L\,O = L\,O' = \tan\frac{\omega}{2}\,(R+H) + E\,O \quad \text{(See fig. 2.)}$$

The angle ϕ is also tabulated.

The offsets at various distances then follow. $O\,C$ equals length of transition. K equals twice the circular measure of angle ϕ, if this quantity is taken from the circular measure of the angle ω, the result is the circular measure of $(\omega - 2\,\phi)$. This quantity being multiplied by the radius, gives the length $C\,C'$. All distances are in links, except where mentioned.

Table 1*a* and 1*b*. These tables are constructed in the same manner as above, and will be found useful to the tramway engineer. Comparing these two tables with Table 1, it will be found easy to extend, as may be required.

Table 2 is similar to Table 1, but by taking $x' = \frac{x_c}{2}$, we eliminate the first quantity given in Table 1. The angle ϕ is not tabulated, but may be obtained from the equation $\tan\phi = \frac{3\,y_c}{x_c}$

Table 3. Extending over several pages, contains the angle θ for every ten links along the curve. Also other data necessary for the location of the parabola. The radius of curvature to the nearest chain is also tabulated.

The following example will illustrate its use.

Having decided upon the radius of the arc $C\ C'$, (See fig. 2.) compute the length $L\ O = L\ O' = \tan \frac{\omega}{2}(R+H)+(x_c - x')$.

Say $R = 10$ chains

Angle $\omega = 50°$

$\therefore L\ O = L\ O' = 660{\cdot}14$

Set instrument at O and for the further illustration, say that the mileage of the point O is 320 m. 4 c. 14·5 l. The next chain to be set out is therefore at a distance 85·5 links from O.

Consulting the table we find at 80 links the angle is 9′ 48″. To obtain the angle corresponding to 85·5 we must multiply the difference 15·6″ by 5·5 = 1′ 25·8″. Adding this to 9′ 48″ we obtain 11′ 14″, neglecting the decimal, this is the angle to be laid out. In a similar manner we obtain the angles corresponding to the mileages

320 m. 6 c. = 52′ 43″

320 m. 7 c. = 2° 4′ 33″

320 m. 8 c. = 3° 45′ 38″

The angle 4° 4′ 40″, and the distance 401·818, brings us to the point C.

It will now be more convenient to move the instrument to A. (See fig. 2.)

$$DA = \text{Sec}\frac{\omega}{2}\ (R+H) - R\ .$$

The arc $C\ C'$ can then be located in the usual manner.

We may set out the arc $C\ C'$ from the point C. Having set the instrument at C, sight to O. Revolve the telescope, towards the axis of X, through the angle $= (\phi - \theta)$, the telescope will then point in the direction of the tangent to C. The curve $C\ C'$ may then be located.

Table 4 is similar to Table 3. The value of y used in the equation to obtain the angles, is found by the formula No. 16.

This table may be called the approximate as it is exactly the same parabola, as that given by Table 2. The radius of curvature being in error to a small extent at the point of contact C.

Table 5 contains the exact value of log "m," to be used in the rigorous method. These values have been computed from equations 3 and 4.

Table 6. This table gives the log cubes, also the log squares of the distance along the axis of X for every ten links. The use of these quantities will be made apparent by the following examples.

Required the offsets to the transition to the ten chain radius arc at the distances 3·50, 3·60 and 3·70 from O along the axis of X.

$$y = m\,x^3 \quad \text{take } x = 4 = x_c$$

$$\log m = 7{\cdot}6489271 \quad \text{(See table 5.)}$$

$$\log x_c{}^3 = 1{\cdot}8061800$$

$$\log y_c = 9{\cdot}4551071$$

$$y_c = 0{\cdot}28517$$

$\log y_c$	$9{\cdot}4551071$	$= 9{\cdot}4551071$	$- 9{\cdot}4551071$
Table (3·50) =	$9{\cdot}8260240$ (3·60) =	$9{\cdot}8627275$	(3·70) = $9{\cdot}8984251$
log offset =	$9{\cdot}2811311$	$9{\cdot}3178346$	$9{\cdot}3535322$
offset =	0·19104	0·20789	0·22570

Again required the angles θ', for a transition to the twelve chain radius arc, $x_c = 4$. The distances along the axis of X being 3·60, 3·70 and 3·80.

We find from the equation $\tan\theta = m\,x_c{}^2 = \frac{y_c}{x_c}$ that

$$\log \tan \theta = 8{\cdot}7477807 \text{ approximate method}$$

log tan $C'OB$ =	$8{\cdot}7477807$	$= 8{\cdot}7477807$	$= 8{\cdot}7477807$
Table (3·60) =	$9{\cdot}9084850$ (3·70) =	$9{\cdot}9322834$	(3·80) = $9{\cdot}9554472$
log tan θ' =	$8{\cdot}6562657$	$8{\cdot}6800641$	$8{\cdot}7032279$
θ' =	2°. 35′. 41·0″	2°. 44′. 26·4″	2°. 53′. 26·0″

The angles for every ten links along the curve are not so easily obtained.

In the computation of their values, the method adopted was a mechanical one. After computing the values as above, for distances along the axis of X, also the corresponding distances along the curve, take the difference $(x - s)$ and interpolate. To be more exact, this difference should be multiplied by the cosine of some angle, the tangent of which is about equal to $\frac{3y}{x}$, before the interpolation is commenced. Table 3 has been computed in this way.

Table 4 has been calculated, having no regard to the cosine of this angle, the angle is small, its cosine is nearly unity, so that it can be eliminated, without having much effect on the result. The second difference has been taken into account in the interpolation.

It may be found impossible to locate the whole curve from the point O. In such a case, the curve may be laid out from the point C. Let $E\,O = x_i$ $O\,B = x_c$ as before. θ_i = angle $B\,C\,O$.

Then we have $\tan\,\theta_i = \frac{x_c - x_i}{m\,(x_c^3 - x_i^3)}$

Appended will be found a list of the formulæ collated.

Formulæ.

$$y = m\,x^3$$

$$\rho = \frac{(1 + 9\,m^2x^4)^{\frac{3}{2}}}{6\,m\,x}. \quad = \frac{\sqrt{(x^2 + 9\,y^2)^3}}{6\,x\,y}. \qquad \rho = \frac{x^2}{6\,y}\text{ (nearly)}$$

$$R = \rho \text{ at the point } C.$$

$$\tan\,\phi = 3\,m\,x_c^2 \text{ or } \tan\,\phi = \frac{3\,y_c}{x_c}.$$

$$D\,B = \tfrac{1}{3}\,x_c. \qquad O\,D = \tfrac{2}{3}\,x_c$$

$$\frac{x_c}{2\,R} = \text{Sin}\,\phi\,\text{Cos}^2\,\phi$$

$$E\,B = x' = R\,\text{Sin}\,\phi. \quad E\,O = x_c - x'.$$

$$G\,T = R - R\,\text{Cos}\,\phi$$

$$H = T\,E = y - G\,T.$$

$$D\,C = y_c\,\text{Cosec}\,\phi. \text{ or } D\,C = \sqrt{\frac{x_c^4 + 9\,y_c^2}{3}}.$$

$$\tan\,\theta = m\,x_c^2. = \frac{y_c}{x_c}.$$

$$\tan \phi = 3 \tan \theta$$

$$x = \sqrt{\frac{\tan \theta}{m}}. \text{ or } \sqrt{\frac{\tan \phi}{3\ m}}.$$

$$\tan \theta_{,} = \frac{x_c - x}{m(x_c{}^3 - x_{,}{}^3)}. \quad \text{Area } A = \frac{x\ y}{4}.$$

$$s = x + \tfrac{9}{10} \frac{y^2}{x} - \tfrac{9}{8} \frac{y^4}{x^3} \text{ etc.}$$

$$s = x\,(1 + \tfrac{9}{10}\ m^2 x^4 - \tfrac{9}{8}\ m^4 x^8 \text{ etc.})$$

$$s = x\,(1 + \tfrac{9}{10} \tan^2 \theta - \tfrac{9}{8} \tan^4 \theta \text{ etc.})$$

$$s = x\,(1 + \cdot 1 \tan^2 \phi - \cdot 0138 \tan^4 \phi \text{ etc.})$$

$$C\ C' = R \left\{ \left[\omega - 2\ (\mathrm{Sin}^{-1} \frac{x'}{R}) \right] \right\} \cdot 0002909$$

$$C\ C' = R \left\{ \left[\omega - 2\ (\mathrm{Sin}^{-1} \frac{x_c}{2\,R}) \right] \right\} \cdot 0002909 \text{ taking } x' = \frac{x_c}{2}$$

$$C\ B = y_c = \tfrac{4}{3} \left\{ R - \sqrt{R^2 - \left(\frac{x_c}{2}\right)^2} \right\} \text{ taking } x' = \frac{x_c}{2}$$

$$\text{and } x_c = \sqrt{6\ R\ y_c - \tfrac{9}{4}\ y_c{}^2}$$

$$L\ O = L\ O' = \tan \frac{\omega}{2} (R + H) + (x_c - x')$$

$$L\ E = L\ E' = \tan \frac{\omega}{2} (R + H)$$

$$D\ A = \mathrm{Sec} \frac{\omega}{2} (R + H) - R$$

$$L\ V = L\ V' = \tan \frac{\omega}{2} H$$

TABLE I.—TABLE OF OFFSETS FOUR-CHAIN TRANSITION CURVE (Exact Method).

Distance in Links from O towards B		Radius at Point of Contact.												
	R	8	9	10	11	12	13	14	15	16	17	18	19	20
	x'	215·68	211·72	209·15	207·37	206·08	205·11	204·35	203·76	203·28	202·89	202·56	202·29	202·06
	H	7·71	7·02	6·40	5·87	5·41	5·02	4·68	4·38	4·11	3·88	3·67	3·48	3·31
		′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″
	ϕ	15 38 25	13 36 21	12 4 21	10 51 59	9 53 19	9 4 40	8 23 36	7 48 26	7 17 57	6 51 16	6 27 42	6 6 43	5 47 55
		Offsets.												
50		0·07	0·06	0·06	0·05	0·05	0·04	0·04	0·04	0·03	0·03	0·03	0·03	0·03
100		0·58	0·50	0·45	0·40	0·36	0·33	0·31	0·29	0·27	0·25	0·24	0·22	0·21
150		1·97	1·70	1·50	1·35	1·23	1·12	1·04	0·96	0·90	0·85	0·80	0·75	0·71
200		4·67	4·03	3·56	3·20	2·91	2·66	2·46	2·29	2·13	2·00	1·89	1·79	1·69
225		6·64	5·74	5·07	4·56	4·14	3·79	3·50	3·25	3·04	2·85	2·69	2·54	2·41
250		9·11	7·88	6·96	6·25	5·67	5·20	4·80	4·46	4·17	3·91	3·69	3·49	3·31
275		12·13	10·49	9·27	8·31	7·55	6·92	6·39	5·94	5·55	5·21	4·91	4·64	4·40
300		15·75	13·61	12·03	10·80	9·81	8·99	8·30	7·71	7·21	6·76	6·37	6·02	5·71
310		17·38	15·02	13·27	11·91	10·82	9·92	9·16	8·51	7·95	7·46	7·03	6·64	6·30
320		19·11	16·52	14·60	13·10	11·90	10·91	10·07	9·36	8·74	8·21	7·73	7·31	6·93
330		20·96	18·12	16·01	14·37	13·05	11·96	11·04	10·27	9·59	9·00	8·48	8·02	7·60
340		22·92	19·82	17·51	15·72	14·27	13·08	12·08	11·23	10·49	9·84	9·27	8·77	8·31
350		25·00	21·62	19·10	17·15	15·57	14·27	13·18	12·25	11·44	10·73	10·12	9·56	9·07
360		27·21	23·52	20·79	18·66	16·95	15·53	14·34	13·33	12·45	11·68	11·01	10·41	9·87
370		29·54	25·54	22·57	20·26	18·40	16·86	15·57	14·47	13·52	12·68	11·95	11·30	10·72
380		32·00	27·67	24·45	21·94	19·93	18·26	16·87	15·67	14·64	13·74	12·95	12·24	11·61
390		34·60	29·91	26·43	23·72	21·54	19·74	18·24	16·94	15·83	14·86	14·00	13·23	12·55
400		37·33	32·27	28·52	25·60	23·24	21·30	19·67	18·28	17·08	16·03	15·10	14·28	13·54
$O\ C$		403·101	402·324	401·818	401·467	401·219	401·018	400·868	400·750	400·655	400·577	400·512	400·458	400·412
K		·5459438	·4749314	·4214090	·3793056	·3451738	·3168714	·2929808	·2725225	·2547898	·2392643	·2255508	·2133442	·2024078

x = Distance $E\ B$. (See figure 1).

H = Distance of parallel tangent.

ϕ = Angle contained between the tangent to the point of contact, and the axis of X.

$O\ C$ = Length of transition curve.

K = Constant to be subtracted from circular measure of the angle ω; the remainder being multiplied by the radius will be the length of arc $C\ C'$. $2\ O\ C + C\ C'$ will be the total length of the curve $O\ O'$.

Offsets to be set out at right angles to $O\ B$ from O towards B.

All measurements are in links, except the radii, which are given in chains.

TABLE Ia.—Table of Offsets Two-Chain Transition Curve. (Exact Method).

Distance in Links from *O* towards *B*	Radius at Point of Contact.				
R	4	5	6	7	8
x'	107·84	104·58	103·04	102·18	101·64
H	3·85	3·20	2·71	2·34	2·06
ϕ	° ′ ″ 15 38 25	° ′ ″ 12 4 21	° ′ ″ 9 53 19	° ′ ″ 8 23 36	° ′ ″ 7 17 57
20	0·02	0·01	0·01	0·01	0·01
40	0·15	0·11	0·09	0·08	0·07
50	0·29	0·22	0·18	0·15	0·13
60	0·50	0·38	0·31	0·26	0·23
70	0·80	0·61	0·49	0·42	0·37
80	1·20	0·91	0·74	0·63	0·55
90	1·70	1·30	1·06	0·90	0·78
100	2·33	1·78	1·45	1·23	1·07
110	3·10	2·37	1·93	1·64	1·42
120	4·03	3·08	2·51	2·12	1·84
130	5·12	3·92	3·19	2·70	2·34
140	6·40	4·89	3·98	3·37	2·93
150	7·87	6·01	4·90	4·15	3·60
160	9·55	7·30	5·95	5·04	4·37
170	11·46	8·76	7·14	6·04	5·24
180	13·60	10·39	8·47	7·17	6·22
190	16·00	12·22	9·96	8·43	7·32
200	18·66	14·26	11·62	9·84	8·54
O C	201·551	200·909	200·605	200·434	200·328
K	0·54594	0·42141	0·34517	0·29298	0·25479

Footnotes same as on Table I.

TABLE Ib.—Table of Offsets One-Chain Transition Curve (Exact Method).

Distance in Links from *O* towards *B*	Radius at Point of Contact.		
R	2	3	4
x'	53·92	51·52	50·82
H	1·93	1·35	1·03
ϕ	° ′ ″ 15 38 25	° ′ ″ 9 53 19	° ′ ″ 7 17 57
20	0·07	0·05	0·03
40	0·60	0·37	0·27
50	1·17	0·72	0·53
60	2·02	1·25	0·92
70	3·20	1·99	1·46
80	4·77	2·97	2·18
90	6·80	4·23	3·11
100	9·33	5·81	4·27
O C	100·775	100·303	100·164
K	0·54594	0·34517	0·25479

Footnotes same as on Table I.

TABLE II.—TABLE OF OFFSETS FOUR-CHAIN TRANSITION CURVE (Approximate Method).

Distance in Links from O towards B	Radius in Chains. 8	9	10	11	12	13	14	15	16	17	18	19	20
	H 8·47	H 7·50	H 6·73	H 6·11	H 5·59	H 5·16	H 4·79	H 4·46	H 4·18	H 3·94	H 3·72	H 3·52	H 3·34
	Offsets.												
50	0·07	0·06	0·05	0·05	0·04	0·04	0·04	0·04	0·03	0·03	0·03	0·03	0·03
100	0·53	0·47	0·42	0·38	0·35	0·32	0·30	0·28	0·26	0·25	0·23	0·22	0·21
150	1·79	1·58	1·42	1·29	1·18	1·09	1·01	0·94	0·88	0·83	0·78	0·74	0·70
200	4·23	3·75	3·37	3·06	2·79	2·58	2·39	2·23	2·09	1·97	1·86	1·76	1·67
225	6·03	5·34	4·79	4·35	3·98	3·67	3·41	3·18	2·98	2·80	2·65	2·51	2·38
250	8·27	7·33	6·58	5·97	5·46	5·04	4·67	4·36	4·09	3·84	3·63	3·44	3·26
275	11·01	9·75	8·75	7·94	7·27	6·71	6·22	5·80	5·44	5·12	4·83	4·57	4·34
300	14·29	12·66	11·37	10·31	9·44	8·71	8·08	7·53	7·06	6·64	6·27	5·94	5·64
310	15·77	13·97	12·54	11·38	10·42	9·61	8·91	8·31	7·79	7·33	6·92	6·55	6·22
320	17·34	15·36	13·79	12·52	11·46	10·57	9·80	9·14	8·57	8·06	7·61	7·21	6·84
330	19·02	16·85	15·13	13·73	12·57	11·59	10·75	10·03	9·40	8·84	8·35	7·90	7·51
340	20·80	18·43	16·54	15·01	13·74	12·67	11·76	10·97	10·28	9·67	9·13	8·64	8·21
350	22·69	20·10	18·05	16·38	14·99	13·82	12·83	11·96	11·21	10·55	9·96	9·43	8·96
360	24·69	21·87	19·64	17·82	16·31	15·04	13·96	13·02	12·20	11·48	10·83	10·26	9·75
370	26·81	23·75	21·32	19·35	17·71	16·33	15·15	14·13	13·24	12·46	11·76	11·14	10·58
380	29·04	25·73	23·10	20·96	19·19	17·69	16·41	15·31	14·35	13·50	12·74	12·07	11·46
390	31·39	27·81	24·97	22·66	20·74	19·13	17·75	16·55	15·51	14·59	13·77	13·05	12·39
400	33·87	30·00	26·94	24·45	22·38	20·64	19·15	17·86	16·73	15·74	14·86	14·08	13·37
$O\,C$	402·56	402·01	401·63	401·33	401·12	400·95	400·82	400·72	400·63	400·56	400·50	400·45	400·40
K	·5053605	·4481862	·4027159	·3656728	·3348962	·3089192	·2866951	·2674632	·2506556	·2358403	·2226820	·2109171	·2003348

H = Distance of parallel tangents. $O\,C$ = Length of transition.

K = Constant to be subtracted from circular measure of the angle ω; the remainder being multiplied by radius will be the length of arc $C\,C$. $2\,O\,C + C\,C'$ will be the total length of curve $O\,O$.

Offsets to be set out at right angles to $O\,B$ from O towards B. All measurements are in links except the radii.

TABLE III.—Four-Chain Transition Curve Value of Angle θ for every Ten Links along Curve.
(Exact Method.)

Radius 8 Chains.						Radius 10 Chains.				
S'	θ'			Difference for 1 Link.	R'	θ'			Difference for 1 Link.	R'
	°	′	″	″		°	′	″	″	
0	0	0	0		∞	0	0	0		∞
				1·2					0·9	
10	0	0	12			0	0	9		
				3·6					2·8	
20	0	0	48			0	0	37		
				6·0					4·6	
30	0	1	48			0	1	23		
				8·5					6·4	
40	0	3	13			0	2	27		
				10·8					8·3	
50	0	5	1		58	0	3	50		75
				13·2					10.1	
60	0	7	13			0	5	31		
				15·6					11·9	
70	0	9	49			0	7	30		
				18·1					13·8	
80	0	12	50			0	9	48		
				20·4					15·6	
90	0	16	14			0	12	24		
				22·9					17·5	
100	0	20	3		29	0	15	19		37
				25·3					19·3	
110	0	24	16			0	18	32		
				27·6					21·1	
120	0	28	52			0	22	3		
				30 1					23·0	
130	0	33	53			0	25	53		
				32·4					24·8	
140	0	39	17			0	30	1		
				34·9					26·6	
150	0	45	6		20	0	34	27		25
				37·2					28·5	
160	0	51	18			0	39	12		
				39·7					30·3	
170	0	57	55			0	44	15		
				42·0					32·2	
180	1	4	55			0	49	37		
				44·4					33·9	
190	1	12	19			0	55	16		
				46·8					35·8	
200	1	20	7		15	1	1	14		19
				49·1					37·6	
210	1	28	18			1	7	30		
				51·5					39·4	
220	1	36	53			1	14	4		
				53·9					41·2	
230	1	45	52			1	20	56		
				56·2					43·1	
240	1	55	14			1	28	7		
				58·5					44·8	
250	2	4	59		12	1	35	35		15
				60·8					46·6	
260	2	15	7			1	43	21		
				63·1					48·4	
270	2	25	38			1	51	25		
				65·3					50·2	
280	2	36	31			1	59	47		
				67·6					52·0	
290	2	47	47			2	8	27		
				69·9					53·7	
300	2	59	26		10	2	17	24		12
				72·1					55·5	
310	3	11	27			2	26	39		
				74·3					57 2	
320	3	23	50			2	36	11		
				76·4					58·9	
330	3	36	34			2	46	0		
				78·5					60·7	
340	3	49	39			2	56	7		
				80·6					62·3	
350	4	3	5		9	3	6	30		11
				82·6					64·0	
360	4	16	51			3	17	10		
				84·6					65·6	
370	4	30	57			3	28	6		
				86·7					67·3	
380	4	45	24			3	39	19		
				88·6					68·9	
390	5	0	10			3	50	48		
				90·4					70·5	
400	5	15	14		8	4	2	33		10

S	403·101	401·818
θ	5° 19′ 53″	4° 4′ 40″
ϕ	15° 38′ 25″	12° 4′ 21″
x'	215·68	209·15
H	7·71	6·40
K	0·5459438	0·4214090

S = Length of Curve. S' = Distance along Curve. θ = Angle corresponding to S. θ' = Angle contained between the radius vector, and the axis of X, corresponding to S'. ϕ = Angle contained between the tangent, at the point of contact, and the axis of X. x' = Distance E B (See fig. 1). H = Distance of parallel tangents. K = Constant to be subtracted from the circular measure of the angle θ. The remainder being multiplied by the radius, will

TABLE III.—*Continued*

Radius 12 Chains.						Radius 14 Chains.				
S'	θ'			Difference for 1 Link.	R'	θ'			Difference for 1 Link.	R'
	°	′	″	″		°	′	″	″	
0	0	0	0		∞	0	0	0		∞
				0·7					0·6	
10	0	0	7			0	0	6		
				2·3					1·9	
20	0	0	30			0	0	25		
				3·7					3·2	
30	0	1	7			0	0	57		
				5·3					4·4	
40	0	2	0			0	1	41		
				6·7					5·7	
50	0	3	7		92	0	2	38		108
				8·3					7·0	
60	0	4	30			0	3	48		
				9·7					8·3	
70	0	6	7			0	5	11		
				11·2					9·5	
80	0	7	59			0	6	46		
				12·8					10·8	
90	0	10	7			0	8	34		
				14·2					12·0	
100	0	12	29		46	0	10	34		54
				15·7					13·3	
110	0	15	6			0	12	47		
				17·3					14·6	
120	0	17	59			0	15	13		
				18·7					15·9	
130	0	21	6			0	17	52		
				20·2					17·1	
140	0	24	28			0	20	43		
				21·7					18·3	
150	0	28	5		31	0	23	46		36
				23·2					19·7	
160	0	31	57			0	27	3		
				24·7					20·9	
170	0	36	4			0	30	32		
				26·2					22·2	
180	0	40	26			0	34	14		
				27·7					23·4	
190	0	45	3			0	38	8		
				29·2					24·7	
200	0	49	55		23	0	42	15		27
				30·7					26·0	
210	0	55	2			0	46	35		
				32·1					27·2	
220	1	0	23			0	51	7		
				33·7					28·5	
230	1	6	0			0	55	52		
				35·1					29·8	
240	1	11	51			1	0	50		
				36·6					31·0	
250	1	17	57		18	1	6	0		22
				38·0					32·2	
260	1	24	17			1	11	22		
				39·5					33·5	
270	1	30	52			1	16	57		
				41·1					34·8	
280	1	37	43			1	22	45		
				42·5					36·0	
290	1	44	48			1	28	45		
				43·9					37·2	
300	1	52	7		15	1	34	57		18
				45·4					38·5	
310	1	59	41			1	41	22		
				46·8					39·7	
320	2	7	29			1	47	59		
				48·2					41·0	
330	2	15	31			1	54	49		
				49·7					42·2	
340	2	23	48			2	1	51		
				51·1					43·3	
350	2	32	19		13	2	9	4		15
				52·5					44·6	
360	2	41	4			2	16	30		
				53·9					45·8	
370	2	50	3			2	24	8		
				55·3					47·0	
380	2	59	16			2	31	58		
				56·6					48·2	
390	3	8	42			2	40	0		
				58·0					49·4	
400	3	18	22		12	2	48	14		14

S	401·210	400·868
θ	3° 19′ 32″	2° 48′ 56″
ϕ	9° 53′ 19″	8° 23′ 36″
x	206·08	204·35
H	5·41	4·68
K	0·3451738	0·2929808

TABLE III.—*Continued.*

Radius 15 Chains.						Radius 16 Chains.				
S'	θ'			Difference for 1 Link.	R'	θ'			Difference for 1 Link.	R'
	°	′	″	″		°	′	″	″	
0	0	0	0		∞	0	0	0		∞
				0·6					0·5	
10	0	0	6			0	0	5		
				1·8					1·7	
20	0	0	24			0	0	22		
				2·9					2·8	
30	0	0	53			0	0	50		
				4·1					3·8	
40	0	1	34			0	1	28		
				5·3					5·0	
50	0	2	27		117	0	2	18		125
				6·5					6·0	
60	0	3	32			0	3	18		
				7·7					7·2	
70	0	4	49			0	4	30		
				8·8					8·2	
80	0	6	17			0	5	52		
				10·0					9·4	
90	0	7	57			0	7	26		
				11·2					10·4	
100	0	9	49		58	0	9	10		62
				12·4					11·6	
110	0	11	53			0	11	6		
				13·5					12·7	
120	0	14	8			0	13	13		
				14·8					13·7	
130	0	16	36			0	15	30		
				15·9					14·9	
140	0	19	15			0	17	59		
				17·1					15·9	
150	0	22	6		39	0	20	38		42
				18·2					17·1	
160	0	25	8			0	23	29		
				19·5					18·2	
170	0	28	23			0	26	31		
				20·6					19·2	
180	0	31	49			0	29	43		
				21·8					20·4	
190	0	35	27			0	33	7		
				22·9					21·5	
200	0	39	16		29	0	36	41		31
				24·1					22·6	
210	0	43	17			0	40	27		
				25·3					23·6	
220	0	47	30			0	44	23		
				26·5					24·8	
230	0	51	55			0	48	31		
				27·7					25·8	
240	0	56	32			0	52	49		
				28·8					26·9	
250	1	1	20		23	0	57	18		25
				30·0					28·0	
260	1	6	20			1	1	58		
				31·1					29·1	
270	1	11	31			1	6	49		
				32·3					30·2	
280	1	16	54			1	11	51		
				33·5					31·3	
290	1	22	29			1	17	4		
				34·6					32·4	
300	1	28	15		19	1	22	28		21
				35·8					33·4	
310	1	34	13			1	28	2		
				37·0					34·6	
320	1	40	23			1	33	48		
				38·1					35·6	
330	1	46	44			1	39	44		
				39·2					36·6	
340	1	53	16			1	45	50		
				40·3					37·7	
350	1	59	59		17	1	52	7		18
				41·5					38·8	
360	2	6	54			1	58	35		
				42·6					39·9	
370	2	14	0			2	5	14		
				43·8					40·9	
380	2	21	18			2	12	3		
				44·9					42·0	
390	2	28	47			2	19	3		
				45·9					43·0	
400	2	36	26		15	2	26	13		16

S	400·750	400·655
θ	2° 37′ 0″	2° 26′ 41″
ϕ	7° 48′ 26″	7° 17′ 57″
x'	203·76	203·28
H	4·38	4·11
K	0·2725225	0·2547898

TABLE III.—*Continued.*

Radius 18 Chains.						Radius 20 Chains.					
S'	θ'			Difference for 1 Link.	R'	θ'			Difference for 1 Link.	R'	
	°	′	″	″		°	′	″	″		
0	0	0	0	0·5	∞	0	0	0	0·4	∞	
10	0	0	5	1·4		0	0	4	1·3		
20	0	0	19	2·5		0	0	17	2·2		
30	0	0	44	3·4		0	0	39	3·1		
40	0	1	18	4·4		0	1	10	3·9		
50	0	2	2	5·3	141	0	1	49	4·8	158	
60	0	2	55	6·3		0	2	37	5·7		
70	0	3	58	7·3		0	3	34	6·5		
80	0	5	11	8·3		0	4	39	7·4		
90	0	6	34	9·3		0	5	53	8·3		
100	0	8	7	10·2	71	0	7	16	9·2	79	
110	0	9	49	11·2		0	8	48	10·0		
120	0	11	41	12·1		0	10	28	10·9		
130	0	13	42	13·1		0	12	17	11·8		
140	0	15	53	14·1		0	14	15	12·7		
150	0	18	14	15·1	47	0	16	22	13·5	53	
160	0	20	45	16·1		0	18	37	14·4		
170	0	23	26	17·0		0	21	1	15·3		
180	0	26	16	18·0		0	23	34	16·1		
190	0	29	16	19·0		0	26	15	17·0		
200	0	32	26	20·0	35	0	29	5	17·9	39	
210	0	35	46	20·9		0	32	4	18·8		
220	0	39	15	21·9		0	35	12	19·6		
230	0	42	54	22·8		0	38	28	20·5		
240	0	46	42	23·8		0	41	53	21·4		
250	0	50	40	24·8	28	0	45	27	22·2	32	
260	0	54	48	25·8		0	49	9	23·1		
270	0	59	6	26·7		0	53	0	23·9		
280	1	3	33	27·7		0	56	59	24·8		
290	1	8	10	28·6		1	1	7	25·7		
300	1	12	56	29·6	24	1	5	24	26·6	27	
310	1	17	52	30·6		1	9	50	27·4		
320	1	23	58	31·5		1	14	24	28·3		
330	1	28	13	32·5		1	19	7	29·1		
340	1	33	38	33·4		1	23	58	30·0		
350	1	39	12	34·3	20	1	28	58	30·9	23	
360	1	44	55	35·3		1	34	7	31·7		
370	1	50	48	36·3		1	39	21	32·5		
380	1	56	51	37·2		1	44	49	33·4		
390	2	3	3	38·1		1	50	23	34·2		
400	2	9	24		18	1	56	5		20	

S	400·512	400·412
θ	2° 9′ 43″	1° 56′ 19″
ϕ	6° 27′ 42″	5° 47′ 55″
x	202·56	202·06
H	3·67	3·31
K	0·2255508	0·2024078

TABLE IV.—Four-Chain Transition Curve Value of Angle θ for every Ten Links along Curve. (Approximate Method.)

Radius 8 Chains.						Radius 10 Chains.					
S'	θ'			Difference for 1 Link.	R'	θ'			Difference for 1 Link.	R'
	°	′	″	″		°	′	″	″	
0	0	0	0		∞	0	0	0		∞
10	0	0	10	1·0		0	0	9	0·9	
20	0	0	43	3·3		0	0	35	2·6	
30	0	1	38	5·5		0	1	18	4·3	
40	0	2	55	7·7		0	2	19	6·1	
50	0	4	33	9 8		0	3	37	7·8	
60	0	6	33	12·0	64	0	5	12	9·5	80
70	0	8	55	14·2		0	7	5	11 3	
80	0	11	39	16·4		0	9	15	13·0	
90	0	14	44	18·5		0	11	43	14·8	
100	0	18	12	20·8		0	14	28	16·5	
110	0	22	1	22·9	32	0	17	30	18·2	40
120	0	26	12	25·1		0	20	50	19·0	
130	0	30	45	27·3		0	24	27	21·7	
140	0	35	39	29·4		0	28	21	23·4	
150	0	40	55	31·6		0	32	33	25·2	
160	0	46	33	33·8	21	0	37	2	26·9	27
170	0	52	33	36·0		0	41	48	28·6	
180	0	58	55	38·2		0	46	52	30·4	
190	1	5	38	40·3		0	52	13	32·1	
200	1	12	43	42·5		0	57	51	33·8	
210	1	20	9	44·6	16	1	3	46	35·5	20
220	1	27	56	46·7		1	9	58	37·2	
230	1	36	5	48 9		1	16	28	39·0	
240	1	44	36	51·1		1	23	15	40·7	
250	1	53	28	53·2		1	30	19	42·4	
260	2	2	40	55·2	13	1	37	40	44·1	16
270	2	12	13	57·3		1	45	17	45·7	
280	2	22	8	59·5		1	53	11	47·4	
290	2	32	24	61·6		2	1	22	49·1	
300	2	43	0	63·6		2	9	50	50·8	
310	2	53	55	65·5	10	2	18	35	52·5	13
320	3	5	10	67·5		2	27	36	54·1	
330	3	16	46	69 6		2	36	54	55·8	
340	3	28	42	71·6		2	46	28	57·4	
350	3	40	57	73·5		2	56	18	59·0	
360	3	53	32	75·5	9	3	6	23	60·5	11
370	4	6	27	77·5		3	16	44	62·1	
380	4	19	40	79 3		3	27	20	63·6	
390	4	33	9	80 9		3	38	12	65·2	
400	4	46	52	82·3		3	49	20	66·8	
					8					10

S	402·56	401·63
θ	4° 50′ 24″	3° 51′ 10″
x'	200	200
H	8·47	6·73
K	0·5053605	0·4027159

S = O C = Length of Curve. θ = Angle corresponding to S. X = Distance along Curve. θ' = Angle contained between the radius vector and the axis of X corresponding to S. x' = Length E B (See fig. 1). H = Distance of parallel tangents. K = Constant to be subtracted from the circular measure of the angle θ. The remainder being multiplied by radius will be the length of arc O C. R' = Radius of Curvature.

TABLE IV.—*Continued.*

Radius 12 Chains.						Radius 14 Chains.				
S'	θ'			Difference for 1 Link.	R'	θ'			Difference for 1 Link.	R'
	°	′	″	″		°	′	″	″	
0	0	0	0	0·7	∞	0	0	0	0·6	∞
10	0	0	7	2·2		0	0	6	1·9	
20	0	0	29	3·6		0	0	25	3·1	
30	0	1	5	5·0		0	0	56	4·3	
40	0	1	55	6·5		0	1	39	5·5	
50	0	3	0	7·9	96	0	2	34	6·8	112
60	0	4	19	9·4		0	3	42	8·0	
70	0	5	53	10·8		0	5	2	9·3	
80	0	7	41	12·3		0	6	35	10·5	
90	0	9	44	13·7		0	8	20	11·7	
100	0	12	1	15·2	48	0	10	17	13·0	56
110	0	14	33	16·6		0	12	27	14·2	
120	0	17	19	18·0		0	14	49	15·4	
130	0	20	19	19·4		0	17	23	16·6	
140	0	23	33	20·9		0	20	9	17·9	
150	0	27	2	22·4	32	0	23	8	19·1	37
160	0	30	46	23·8		0	26	19	20·4	
170	0	34	44	25·2		0	29	43	21·6	
180	0	38	56	26·7		0	33	19	22·8	
190	0	43	23	28·1		0	37	7	24·0	
200	0	48	4	29·5	24	0	41	7	25·3	28
210	0	52	59	31·0		0	45	20	26·5	
220	0	58	9	32·4		0	49	45	27·7	
230	1	3	33	33·8		0	54	22	29·0	
240	1	9	11	35·2		0	59	12	30·2	
250	1	15	3	36·7	19	1	4	14	31·4	22
260	1	21	10	38·1		1	9	28	32·6	
270	1	27	31	39·5		1	14	54	33·8	
280	1	34	6	40·9		1	20	32	35·0	
290	1	40	55	42·3		1	26	22	36·2	
300	1	47	58	43·7	16	1	32	24	37·5	19
310	1	55	15	45·1		1	38	39	38·7	
320	2	2	46	46·5		1	45	6	39·9	
330	2	10	31	47·9		1	51	45	41·1	
340	2	18	30	49·2		1	58	36	42·2	
350	2	26	42	50·5	14	2	5	38	43·4	16
360	2	35	7	51·9		2	12	52	44·6	
370	2	43	46	53·3		2	20	18	45·7	
380	2	52	39	54·6		2	27	55	46·9	
390	3	1	45	56·0		2	35	44	48·1	
400	3	11	5		12	2	43	45		14

S	401·12	400·82
θ	3° 12′ 8″	2° 44′ 25″
x'	200	200
H	5·59	4·79
K	0·3348962	0·2866951

TABLE IV.—*Continued.*

Radius 15 Chains.						Radius 16 Chains.					
S'	θ'			Difference for 1 Link.	R'	θ'			Difference for 1 Link.	R'	
	°	′	″	″		°	′	″	″		
0	0	0	0		∞	0	0	0		∞	
				0·6					0·5		
10	0	0	6			0	0	5			
				1·7					1·6		
20	0	0	23			0	0	21			
				2·9					2·7		
30	0	0	52			0	0	48			
				4·0					3·8		
40	0	1	32			0	1	26			
				5·2					4·9		
50	0	2	24		120	0	2	15		128	
				6·3					5·9		
60	0	3	27			0	3	14			
				7·5					7·0		
70	0	4	42			0	4	21			
				8·6					8·1		
80	0	6	8			0	5	45			
				9·8					9·2		
90	0	7	46			0	7	17			
				10·9					10·2		
100	0	9	35		60	0	8	59		64	
				12·1					11·3		
110	0	11	36			0	10	52			
				13·3					12·4		
120	0	13	49			0	12	56			
				14·4					13·5		
130	0	16	13			0	15	11			
				15·5					14·6		
140	0	18	48			0	17	37			
				16·7					15·6		
150	0	21	35		40	0	20	13		42	
				17·8					16·7		
160	0	24	33			0	23	0			
				19·0					17·8		
170	0	27	43			0	25	58			
				20·1					18·9		
180	0	31	4			0	29	7			
				21·3					20·0		
190	0	34	37			0	32	27			
				22·4					21·0		
200	0	38	21		30	0	35	57		32	
				23·6					22·1		
210	0	42	17			0	39	38			
				24·7					23·1		
220	0	46	24			0	43	29			
				25·9					24·2		
230	0	50	43			0	47	31			
				27·0					25·3		
240	0	55	13			0	51	44			
				28·1					26·4		
250	0	59	54		24	0	56	8		26	
				29·3					27·5		
260	1	4	47			1	0	43			
				30·5					28·5		
270	1	9	52			1	5	28			
				31·6					29·6		
280	1	15	8			1	10	24			
				32·7					30·7		
290	1	20	35			1	15	31			
				33·8					31·7		
300	1	26	13		20	1	20	48		21	
				34·9					32·7		
310	1	32	2			1	26	15			
				36·1					33·8		
320	1	38	3			1	31	53			
				37·2					34·9		
330	1	44	15			1	37	42			
				38·3					36·0		
340	1	50	38			1	43	42			
				39·5					37·0		
350	1	57	13		17	1	49	52		18	
				40·6					38·0		
360	2	3	59			1	56	12			
				41·6					39·1		
370	2	10	55			2	2	43			
				42·7					40·1		
380	2	18	2			2	9	24			
				43·9					41·1		
390	2	25	21			2	16	15			
				44·9					42·2		
400	2	32	50		15	2	23	17		16	

S	400·72	400·63
θ	2° 33′ 22″	2° 23′ 43″
x	200	200
H	4·46	4·18
K	0·2674632	0·2506556

TABLE IV—*Continued.*

Radius 18 Chains.						Radius 20 Chains.				
S'	θ'			Difference for 1 Link.	R'	θ'			Difference for 1 Link.	R'
	°	′	″	″		°	′	″	″	
0	0	0	0		∞	0	0	0		∞
10	0	0	5	0·5		0	0	4	0·4	
20	0	0	19	1·4		0	0	17	1·3	
30	0	0	43	2·4		0	0	39	2·2	
40	0	1	17	3·4		0	1	9	3·0	
50	0	2	0	4·3	144	0	1	48	3·9	160
60	0	2	52	5·2		0	2	35	4·7	
70	0	3	55	6·3		0	3	31	5·6	
80	0	5	7	7·2		0	4	36	6·5	
90	0	6	28	8·1		0	5	49	7·3	
100	0	7	59	9·1	72	0	7	11	8·2	80
110	0	9	40	10·1		0	8	41	9·0	
120	0	11	30	11·0		0	10	20	9·9	
130	0	13	30	12·0		0	12	8	10·8	
140	0	15	39	12·9		0	14	4	11·6	
150	0	17	58	13·9	48	0	16	9	12·5	53
160	0	20	26	14·8		0	18	23	13·4	
170	0	23	4	15·8		0	20	45	14·2	
180	0	25	52	16·8		0	23	16	15·1	
190	0	28	49	17·7		0	25	55	15·9	
200	0	31	56	18·7	36	0	28	43	16·8	40
210	0	35	12	19·6		0	31	40	17·7	
220	0	38	38	20·6		0	34	45	18·5	
230	0	42	13	21·5		0	37	59	19·4	
240	0	45	58	22·5		0	41	21	20·2	
250	0	49	52	23·4	29	0	44	52	21·1	32
260	0	53	56	24 4		0	48	31	21·9	
270	0	58	10	25·4		0	52	19	22 8	
280	1	2	33	26·3		0	56	16	23·7	
290	1	7	5	27·2		1	0	21	24·5	
300	1	11	47	28·2	24	1	4	35	25·4	27
310	1	16	38	29·1		1	8	57	26·2	
320	1	21	39	30·1		1	13	27	27·0	
330	1	26	49	31·0		1	18	6	27·9	
340	1	32	8	31·9		1	22	54	28·8	
350	1	37	37	32·9	20	1	27	50	29·6	23
360	1	43	15	33·8		1	32	55	30·5	
370	1	49	3	34·8		1	38	8	31·3	
380	1	55	0	35·7		1	43	29	32·1	
390	2	1	6	36·6		1	48	59	33·0	
400	2	7	21	37·5	18	1	54	37	33·8	20

S	400·50	400·40
θ	2° 7′ 40″	1° 54′ 50″
x'	200	200
H	3·72	3·34
K	0·2226820	0·2003348

TABLE V.—Values of Log "*m*."

(Argument *R* and *x*.)

R	*x* = 4	*x* = 3	*x* = 2	*x* = 1
2				8·9699750
3				8·7642285
4			8·3679151	8·6303900
5			8·2509871	8·5295623
6		8·0157325	8·1621686	
7		7·9337197	8·0897505	
8	7·7658550	7·8668664	8·0283300	
9	7·7026316	7·8099861	7·9748791	
10	7·6489271	7·7602863	7·9275024	
11	7·6019691	7·7160541		
12	7·5601087	7·6761475		
13	7·5222665	7·6397610		
14	7·4876906	7·6063020		
15	7·4558304	7·5753197		
16	7·4262700			
17	7·3986855			
18	7·3728191			
19	7·3484620			
20	7·3254423			

TABLE VI.—*x* = 4 Chains.

Dist. in Chains.	Log Cube of Distance.	Log Square of Distance.
·10	5·1938200	6·7958800
·20	6.0969100	7·3979400
·30	6·6251839	7·7501226
·40	7·0000000	8·0000000
·50	7·2907300	8·1938200
·60	7·5282739	8·3521826
·70	7·7291140	8·4860760
·80	7·9030900	8·6020600
·90	8·0565475	8·7043650
1·00	8·1938200	8·7958800
1·10	8·3179981	8·8786654
1·20	8·4313636	8·9542424
1·30	8·5356502	9·0237688
1·40	8·6322040	9·0881360
1·50	8·7220939	9·1480626
1·60	8·8061800	9·2041200
1·70	8·8851667	9·2567775
1·80	8·9596375	9·3064250
1·90	9·0300808	9·3533872
2·00	9·0969100	9·3979400
2·10	9·1604779	9·4403186
2·20	9·2210881	9·4807254
2·30	9·2790034	9·5193356
2·40	9·3344536	9·5563022
2·50	9·3876400	9·5917600
2·60	9·4387399	9·6258266
2·70	9·4879114	9·6586075
2·80	9·5352940	9·6901960
2·90	9·5810140	9·7206750
3·00	9·6251839	9·7501226
3·10	9·6679051	9·7786134
3·20	9·7092700	9·8061800
3·30	9·7493617	9·8329075
3·40	9·7882567	9·8588375
3·50	9·8260240	9·8840160
3·60	9·8627275	9·9084850
3·70	9·8984251	9·9322884
3·80	9·9331708	9·9554472
3·90	9·9670138	9·9780002
4·00	0·0000000	0·0000000

THE HISTORY, THEORY, AND DETERMINATION OF THE VISCOSITY OF WATER BY THE EFFLUX METHOD.

By G. H. KNIBBS, Lecturer on Surveying, University of Sydney.

[With Plate XI.]

[*Read before the Royal Society of N. S. Wales, July 3, 1895.*]

I.—History.
II.—The Theory of Efflux.
III.—Determination of the Viscosity.
IV.—Indications for a further Determination.

I.—HISTORY.

1. The recognition of the existence of internal friction in fluids, and of its physical importance, was naturally followed by investigations to determine its amount. Each observer's measurements are in general, fairly consistent among themselves, but when compared with others, discrepancies are found ranging over somewhat wide limits. This is true, even where the schemes of observation have been identical: where they have differed the divergence of results is very marked.

In the case of water, the measure of the internal friction, expressed by the coëfficient of viscosity, has been deduced from observations of the following types, viz. of—

(*a*) the decrement in the oscillations in U-shaped tubes:
(*b*) the decrement in the oscillation of submerged discs:
(*c*) the volumes of efflux from capillary tubes:
(*d*) the decrement in the torsional oscillations about an axis of spheres filled with water:
(*e*) the tangential force on the inner one of a pair of coäxial cylinders, exerted by the liquids lying between, when the outer one is rotated:
(*f*) a method similar to (*e*) the cylinders being replaced by spheres.

In regard to the third method, (*c*), with which we are here more immediately concerned, it may be said, that although the

general theory of flow in small tubes, which contributed the formulæ employed in its analysis, leaves little to be desired, that of the application of important corrections to the experimental data has been considerably improved, and the whole problem been brought more into line with rational mechanics. This, no less than the fact that former reductions are sometimes not entirely free from error of principle, indicates the desirableness of a more rigorous analysis of observations by the efflux method, and an inquiry as to the most suitable disposition of apparatus when accurate results are desired. It will be shown also, that to reach the highest possible degree of precision obtainable from experimental data, corrections heretofore ignored must be considered, and that the magnitudes of corrections already recognised in theory, are to some extent uncertain, so that for measurements of great precision recourse must be had to methods of observation permitting of their elimination. The manner in which this may be effected will be illustrated, and a new reduction of the numerous observations will be undertaken, in which so far as the data permit, all the necessary corrections will be made.

2. *History and Literature.*—The recognition of the importance of a measurement of the viscosity of water seems to have originated in the practical requirements of hydraulicians; the efforts of Mariotte,[1] Guglielmini, Daniel Bernouilli,[2] Couplet,[3] D'Alembert,[4] Bossut,[5] and Dubuat,[6] to establish a satisfactory theory of the flow of water compelled their attention to the subject. Prony[7] expresses

[1] Traité du mouvement des eaux—Paris, 1686.

[2] Theoria nova de motu aquarum per canales quòcunque fluentes.—Acad. St. Petersbourg, 1726.

[3] Recherches sur le mouvement des eaux.—Hist. l'Acad. roy. des Sciences, 1732.

[4] Essai sur la résistance des fluides, 1752.

[5] Traité élémentaire d'hydrodynamique—Paris, 1775; and Nouvelles expériences sur la resistance des fluides, 1777.

[6] Principes d' hydraulique, verifiés par un grand nombre d' expériences.—Paris, 1779.

[7] Recherches physico-mathématiques sur la théorie des eaux courantes.—Paris, 1804.

his regret that Euler, who in the course of his great labours often directed his attention to physico-mathematical problems, failed to treat the theory of the motion of fluids having regard to molecular cohesion and to some sort of internal friction (quelque espèce de frottement).

The first attempt to measure the viscosity of water, so far as I am aware, was Lambert's,[1] about 1784, and was made by observing oscillations in U-shaped tubes. Coulomb's[2] celebrated measurements by means of oscillating discs followed about 1799 or 1800. He expressed the frictional resistance under the form $au+bu^2$, u denoting lineal velocity and a and b constants depending upon the physical constitution of the liquid, a form earlier employed by Newton,[3] Bernoulli, and s'Gravesande[4] to express the resistance of the atmosphere. Coulomb practically ignored the influence of temperature in his experiments, stating that between the limits 10° and 16° Reaum.[5] its effect was insensible. Gerstner[6] however, had in 1798 noticed that the flow of water in small tubes varied very perceptibly with temperature, demonstrating the fact by a series of experiments at Prague. In 1816 Girard[7] continued the observation of flow in capillary tubes and deduced a formula, which however had no generality and must be regarded as erroneous. Nothing in the way of experiment seems then to have been made till about 1840, but it should be remembered that in this

---

[1] Sur les fluides considérés relativement à l'hydrodynamique.—Mém. l'Acad. de Berlin, 1784.

[2] Expériences destinées à déterminer la cohérence des fluides et les lois de leur résistance dans les mouvements très lents.—Mém. de l' Institut National, t. 3, p. 261.

[3] Newton used $au+bu^{\frac{3}{2}}+cu^2$.—Vide the Principia Lib II. Prop. XXXI.

[4] Philosophiæ Newtonaniæ Institutiones. [5] *Loc. cit.* p. 349.

[6] Versuche über die Flüssigkeit des Wassers bei verschiedenen Temperaturen.—Abhandl. Böhm Gesell. der Wiss. Prag Bd. 3, phys-math. Th. p. 141–160, 1798.

[7] Mém. sur le mouvement des fluides dans les tubes capillaires et l'influence de la température sur ce mouvement.—Mém. l'Acad. t. 1, p. 188–274.

interval Navier[1] published his celebrated memoir in which the theory of the motion of a viscous fluid is mathematically treated. The memoir was read in January 1817 at the French Academy of Sciences. Shortly before 1835 the attention of Poiseuille[2] was strongly directed to the subject of venous and arterial flow, to establish the laws of which on a rational basis,[3] he undertook, about 1838, a lengthy investigation of flow in capillary tubes. This enabled him to correctly enunciate the law of flow for such tubes, and to furnish an expression for the efflux therefrom between the temperature limits 0° and 45° centigrade. His experiments remain, I venture to think, unrivalled even to-day, as regards their general precision. Girard's formula previously mentioned, and Navier's intrinsically identical therewith, but theoretically established, were shown to be inapplicable in regard to efflux from capillaries. These researches were published in great detail in 1846, in the Mémoires des savants étrangers, and, as we shall see later on, supply material for determining the viscosity with a high degree of precision, and for testing the validity of and evaluating the constants of necessary corrections, to be applied to the immediate data of any observation. Poiseuille himself did not, however, deduce the viscosity coëfficient, nor recognize the necessity for the corrections, and his enunciation of the law, though accurate, left the matter in the empirical stage.

Before the above mentioned publication tolerably complete information had already appeared from time to time in the 'Comptes rendus' as to the scope and results of these researches, and in April 1845, that is before the detailed results had appeared, Stokes,[4] in his contribution to the mathematical theory of internal

[1] Mémoire sur les lois du mouvement des fluides.—Mém. de l'Acad. roy. des Sc. t. 6, p. 389 - 440, 1823.

[2] Recherches expérimentales sur le mouvement des liquides dans les tubes de très-petits diamètres.—Mem. des Sav. étrang. t. 9, p. 433 - 543.

[3] Physiologists and pathologists had attributed the power of spontaneous movement to blood corpuscles.—Ibid, p. 433.

[4] On the theories of the internal friction of fluids in motion and of the equilibrium and motion of elastic solids.—Trans. Phil. Soc., Cambridge, Vol. 8, p. 287 - 319, 1849.

friction, gave I believe, the first rational interpretation of the law of flow in long narrow tubes.

In 1847 Moritz followed with some observations on Coulomb's[1] method. Seven years later (1854) Hagen[2] attempted a more general solution of flow in narrow tubes, following much on Gerstner's lines. In 1858 Ludwig and Stefan[3] made an important contribution to the theory of this subject, but it was not until January 1860, that the viscosity coëfficient appearing in the equations of Navier was included in an exact and general formula for the efflux from tubes: it then appeared in Jacobson's[4] contribution to haemodynamics. This furnished the results of a somewhat extensive series of efflux experiments, and gave an exposition, credited to Neumann,[5] of the theory of flow in cylindrical tubes of circular section. The date of the first publication of this exposition I have not been able to ascertain, but it must have been prior to 1860. It contained an accurate and complete deduction of the law of velocity in a right circular cylinder, on the assumption of a velocity at the boundary of the liquid; employed terms to represent the internal friction and that at the boundary; and showed that when the boundary velocity was zero Poiseuille's law was obtained. It dealt moreover with the fall in pressure at the entrance to a tube, basing the formula for its amount on Newton's value for the coëfficient of flow for short cylindrical adjutages. It is also worthy of remark that the viscosity is expressed in the absolute system in Jacobson's treatise, and that he experimentally showed that the law held for larger tubes than were used by Poiseuille.

---

[1] Einige Bemerkungen über Coulomb's Verfahren, die Cohäsion der Flüssigkeiten zu bestimmen.—Pogg. Annalen. Bd. 70, p. 74–85, 1847.

[2] Ueber die Bewegung des Wassers in engen cylindrischen Rohren.—Abhandl. d königl. Akad. d Wiss. zu Berlin, 1854, Math. Abt. p. 17.

[3] Ueber den Druck den das fliessende Wasser senkrecht zu seiner Stromrichtung ausübt.—Sitzber. Akad. Wien., Bd. 32, p. 25–42, 1858.

[4] Beiträge zur Haemodynamik.—Archiv für Anat. und Physiol. 1860, p. 80–113.

[5] Vorträge über Hydrodynamik.

Hagenbach's[1] memoir was published in March 1860. He deduced the general formula for flow in indefinitely long narrow tubes of circular section, in which the velocity is zero at the sides of the tubes, and considered the fall of pressure occurring at the entrance of the tube, for which he furnished a formula. This formula, though somewhat inexact, has been used for correcting observed differences of pressures, at the tube terminals, by nearly all subsequent observers.

Almost contemporaneously with Hagenbach's memoir, the date of publication being but one month later, the results of Helmholtz's and Piotrowski's[2] researches appeared, the latter dealing with the experimental, and the former with the theoretical side of the subject. In their joint memoir Helmholtz developed an expression for flow in narrow tubes of circular section intrinsically identical as regards its first term with Hagenbach's, but containing in addition a second term representing the influence of friction at the boundary of the flowing liquid. This Helmholtz and his colleague deemed necessary in a complete formula, in view of the fact that their experiments pointed to the existence of a relative movement and consequent frictional effect at the boundary common to the liquid and the containing vessel, at any rate as between a polished gilt surface and water, and their formula is substantially identical with the earlier formulæ of Neumann or Jacobson. Neither Hagenbach nor Helmholtz refer to any earlier correct expression for steady rectilinear motion in pipes of circular section, and it is somewhat remarkable that it is generally credited to the latter, although so far as I can ascertain, Stokes, Neumann, and Hagenbach all have a prior claim to this credit. A second and very valuable discussion by Jacobson[3] of the theory of rectilinear flow and evaluation of viscosity was communicated in September

[1] Ueber die Bestimmung der Zähigkeit einer Flüssigkeit durch den Ausfluss aus Röhren.—Pogg. Annal. Bd. 109, p. 384–426, 1860.

[2] Ueber Reibung tropfbarer Flüssigkeiten.—Sitzber. k. k. Akad. Wien., Bd. 40, p. 607–658, 1860.

[3] Zur Einleitung in die Hæmodynamik.—Archiv. für Anat. und Phys. 1861, p. 304–328.

1860 to a meeting of physicists at Königsberg, and in this the results of measurements of efflux for temperatures up to 71·5° C. were given.

Magnus[1] experiments in 1850 and 1855 should perhaps have been mentioned as affording physical illustrations of viscosity; they contributed however nothing of moment in regard to its numerical evaluation. At this period the general significance and importance of the viscous property of fluids was forcing itself strongly upon the attention of physicists, particularly perhaps in the direction of chemical physics, and in 1861 Graham's[2] essay appeared "On liquid transpiration in regard to chemical composition," an early contribution in that department of research. Graham's work is of interest to our present purpose mainly because in his measurements of flow through capillary tubes he also greatly extended the range of temperature beyond Poiseuille's limits, carrying it as far as 70° C.—*i.e.* 25° beyond Poiseuille—and also because he made measurements for every degree up to 5°. Had his experiments been more accurate they would have afforded an opportunity of examining whether the mathematical expression of the law of viscosity showed any peculiarity at the temperature of maximum density.

In the same year (1861) Meyer's[3] first contribution to the theory of internal fluid friction, and to experimental research therein, was published. Seven years later (1868) at Bonn, Rellstab's[4] dissertation on the transpiration of similar fluids traversed the subject, and gave also the results of some new measurements by

[1] Ueber die Bewegung der Flüssigkeiten.—Pogg. Annal. Bd. 80, p. 1–30, 1850. Also, Hydraulische Untersuchungen.—Pogg. Annal. Bd. 95, p. 1–59, 1855.

[2] Phil. Trans. Roy. Soc. Lond., Vol. 151, p. 373–386, 1861.

[3] Ueber die Reibung der Flüssigkeiten (Theoretischer Teil).—Crelle Journ. Math. Bd. 59, p. 229–303, 1861, and same title, Pogg. Annal. Bd. 113, p. 55–86, p. 193–238, and p. 383–245, 1861.

[4] Ueber die Transpiration homologer Flüssigkeiten.—Inauguraldissertation, Bonn, 1868.

the efflux method. In 1876 Sprung[1] made a series of experiments with water in connection with his physico-chemical researches. The following year Meyer communicated the results of Rosencranz's[2] observations, the latter having died at Breslau in February of that year, *i.e.* in 1877. Rosencranz's investigation, in which measurements up to 90° C. were made, had for its object the extension of the values of the viscosity coëfficient beyond Poiseuille's limits, with the view of ascertaining how far Poiseuille's formula, accurately expressing the effect of temperature under a simple algebraic form, could be safely extrapolated.

The viscosity research in the department of chemical physics was continued by Přibram and Handl[3] in 1878 and 1879, and by Grotrian[4] in 1879, the latter furnishing further observations by the efflux method, and drawing attention to an analogy between fluidity and electric conductivity. Slotte[5] in 1881, and Wagner[6] in 1883, the latter continuing a line of physico-chemical research commenced by him in 1876, both supply efflux measurements for water made in connection with their investigation of the internal frictions of chemical solutions.

In the year last mentioned, Reynolds[7] demonstrated afresh that the law of flow in capillary tubes held also for larger tubes, provided

---

[1] Experimentelle Untersuchungen über die Flüssigkeitsreibung bei Salzlösungen, Bd. 159, p. 1 – 35, 1876.

[2] Beobachtungen von Adolf Rosencranz über den Einfluss der Temperatur auf die innere Reibung von Flüssigkeiten: mitgeteilt von O. E. Meyer.—Wied. Annal. Bd, 2, p. 387 – 406, 1877.

[3] Ueber die specifische Zähigkeit der Flüssigkeiten und ihre Beziehung zur chemische Constitution.—Sitzber. k. k. Akad. Wien. Bd. 78, Abt. 2, p. 113 – 164, 1878, and Bd. 80, Abt. 2, p. 17 – 57, 1879.

[4] Analogien zwischen der Fluidität und dem galvanischen Leitungsvermögen.—Wied. Annal. Bd. 8, p. 529 – 554, 1879.

[5] Ueber die innere Reibung der Lösungen einiger Chromate.—Wied. Annal. Bd. 14, p. 13 – 22, 1881.

[6] Ueber die Zähigkeit von Salzlösungen.—Wied. Annal. Bd. 18, p. 259 – 289, 1883

[7] An experimental investigation &c., &c., and of the law of resistance in parallel channels.—Phil. Trans. Vol. 174, p. 935, 1883.

the velocities were sufficiently small. He was under the impression that this had not already been done, but as previously pointed out Jacobson had anticipated him. Although Reynolds' experiments are not suitable for the derivation of an exact value for viscosity, it may be observed that his results are consistent with Poiseuille's. In 1884, Röntgen[1] and Warburg and Sachs[2] examined the influence of pressure and density upon this coëfficient and the year following König[3] ascertained that there was no sensible difference in the time of efflux when it took place in a powerful magnetic or electric field. He made some further measurements[4] in 1887 but not by the efflux method.

The next important contribution is Couette's[5] whose experiments embrace two methods, viz. that of measuring the tangential force on an internal cylinder exerted by liquids lying between it and a coäxial outer rotated cylinder—method (*e*)—and that of efflux (*c*). In regard to the latter it may be said that he considerably advanced the theory of the correction of the pressures registered by the manometers in the vessels at the terminals of the tubes, and indicated a method of observation by which the corrections may be entirely eliminated. Couette's correction for the fall of pressure at the entrance of the capillary, though more exact than Hagenbach's (1860), and very much more exact than Reynold's (1883) was theoretically demonstrated by Boussinesq[6] in 1891 to be true

[1] Ueber den Einfluss des Druckes auf die Viscosität der Flüssigkeiten, speciell des Wassers.—Wied. Annal. Bd. 22, p. 510–518, 1884.

[2] Ueber den Einfluss der Dichtigkeit auf die Viscosität tropfbarer Flüssigkeiten.—Wied. Annal. Bd. 22, p. 518–522, 1884.

[3] Bestimmung einiger Reibungscoëfficienten und Versuche über den Einfluss der Magnetisirung und Electrisirung auf die Reibung der Flüssigkeiten.—Wied. Annal. Bd. 25, p. 618–625, 1885.

[4] Ueber die Bestimmung von Reibungscoëfficienten tropfbarer Flüssigkeiten mittelst drehender Schwingungen.—Wied. Annal. Bd. 32, p. 193, 1887.

[5] Études sur le frottement de liquides.—Annal. de Chim. et de Physique 6 Ser. t. 21, p. 433–510, 1890.

[6] Sur la manière dont les vitesses dans un tube cylindrique de section circulaire, évasé à son entrée, se distribuent depuis cette entrée jusqu' aux endroits où se trouve établi un régime uniforme.—Comptes Rendus, t. 113, p. 9–15, 1891. Calcul de la moindre longueur que doit avoir un tube circulaire, évasé à son entrée pour qu' un régime sensiblement uniforme s'y établisse et de la dépense de charge qu'y entraîne l'établissement de ce régime.—Ibid, p. 49.

only to a first approximation : a higher approximation requires that it be increased about one-eighth, and it will be shown that Boussinesq's theory is experimentally vindicated. In the same year (1891) Brodmann[1] published the results of his researches with the sphere and cylinder methods—(f) and (e)—and showed that with both, but especially with the former, different values were obtained for the viscosity according to the size of the sphere or of the cylinder, confirming Elie's[2] observation that values for the viscosity deduced from experiments with concentric spheres by Kirchhoff's formula, increased with the velocity of rotation. In 1892 Cohen,[3] employing the efflux method, continued the research in respect of the influence of pressure on the coëfficient, for the temperatures 1°, 15°, and 23° C., and for pressures up to 900 atmospheres. His results therefore add to the material for comparison.

Many other contributors either to the theory or observation of the viscosity of liquids, or cognate matters, might be mentioned—as for example, Hübener 1873, Baumgartner '74, Guerout '74 and '76, Villari '76, Koch '81, Grossmann '83, Graetz '88, Wirtz '89, Whetham '90, Brückner '90 and '91, and Rayleigh '92—but the above sketch of the course of the investigation embraces its main historical outlines and subsequent references will be made only to such of the above as especially bear upon the particular element of any question under review.

II.—The Theory of Efflux.

3. *Equation of Flux in a narrow right circular cylinder.*—It was shown by Helmholtz in 1860[4] that if a flow of incompressible fluid be established in a long cylindrical capillary tube, in section

[1] Untersuchungen über den Reibungscoëfficienten von Flüssigkeiten. Inauguraldissertation, Gottingen, 1891.—Wied. Annal. Bd. 45, p. 153-184, 1892.

[2] Variation du coefficient de viscosité avec la vitesse.—Journal de Physique, Sér. 2, t. 1, p. 224, 1882.

[3] Ueber den Einfluss des Druckes auf die Viscosität von Flüssigkeiten. —Wied. Annal. Bd. 45, p. 666 - 684, 1892.

[4] Sitzber. Akad Wiss. Wien. Bd. 40, p. 653, 1860.

a circle of radius R, and the pressure in a length L of the tube fall from p_0 to p_1, the volume q flowing in a unit of time across any right section of the tube is expressed by the equation :—

$$q = \frac{\pi(p_0 - p_1)}{8\,k^2\,L}(R^4 + 4\,b\,R^3)$$

in which k^2 is a constant determined by the internal resistance of the fluid, b one depending on the friction at its boundary, and π is 3·14159 etc. In recent treatises on hydrodynamics[1] the equation is usually written

$$q = \frac{\pi(p_0 - p_1)}{8\,\eta\,L}\left(R^4 + 4\,\frac{\eta}{\beta}R^3\right) \ldots\ldots\ldots\ldots\ldots(1).$$

η or Helmholtz's k^2, being the coëfficient of viscosity, and β that of sliding friction. This latter form is the earlier and the better, and is essentially that deduced by Neumann some time prior to 1860. The reciprocal of the viscosity, $f = 1/\eta$, has been called the coëfficient of fluidity and $1/\beta$ that of slipping.

4. *Limitation of the Equation of flux.*—The movements of liquids may be classed under two régimes, a fact clearly recognized by Darcy[2] in 1857, and since illustrated in a striking manner by the experiments of Reynolds[3] in 1883, and confirmed by those of Couette[4] in 1888. In the first régime no eddies are formed, and the liquid, if limpid, has what has not inaptly been called a "plate-glass" appearance. In the second, eddies or vortices are formed, and the "sheet-glass" appearance may be noted, the refraction of the liquid being varied by the eddies. It is to flow under the first régime, that is to flow without vortices, that the

[1] Kirchhoff, Vorlesungen über mathematische Physik (1883 edit.) p. 373. Bassett—Treatise on Hydrodynamics, 1888 Edit. Vol. II., p. 305. Lamb—A treatise on the motion of fluids, 1879 Edit. p. 224. Lamb uses μ/ρ for η/ρ or Bassett's ν, being what has been called by Maxwell the kinematic coëfficient of viscosity, *i.e.* η/ρ, ρ denoting the density of the fluid.

[2] Recherches expérimentales relatives au mouvement de l'eau dans les tuyaux, Paris 1857. See also Mém. des Savants étrangers t. 15, p. 215 et 354.

[3] Phil. Trans. Vol. 174, p. 935–982.

[4] Annal. de Chimie, 6 Sér. t. 21, p. 464.

above equation applies. The physical characteristic of such a flow in a cylindrical pipe, is that the motion of all particles is parallel to its axis, and points of equal velocity lie, if the section be a circle, in the circumference of a circle concentric therewith, the velocity of course diminishing with increase of distance from the axis. The liquid may therefore be imagined to be divided into a series of coäxial circular cylinders, and the internal friction to be the sum of the resistances exercised by each cylindrical stratum upon the interior and more rapidly moving cylinder. It is this conception, viz. that of steady rectilinear motion, which, together with the consideration of the boundary condition, leads to the formula written.

5. *Definition of Viscosity.*—Navier,[1] in his treatise, gives an explanation rather than a definition of the meaning of η (ϵ in his equations), which may be thus expressed:—If we imagine a fluid to be divided into a series of planes parallel to some fixed plane, the motion in each being identical in direction, and in velocity equal to its distance from the plane, then the constant η represents in units of weight, the resistance per unit of surface to the sliding of one stratum on another. Hagenbach's[2] definition is:—By viscosity we denote the force necessary to move with uniform velocity and in a unit (second) of time a stratum of fluid one molecule in thickness and of unit surface, the distance of two molecules past a second stratum. Both definitions lack generality, the latter being moreover dependent upon a particular conception as to the physical constitution of a fluid. The following is proposed as obviating these objections:—The coëfficient of viscosity expresses the *ratio*, per unit of surface, of the tangential resistance between parallel strata of a fluid moving with different velocities, to the rate of variation of their velocity measured perpendicularly to the direction of movement. The resistance is consequently supposed to vary as the difference of the velocity, an assumption

[1] Mém. l'Acad. des Sciences, t. 6, p. 416.

[2] Pogg. Annal. Bd. 109, p. 425. The translation is nearly literal.

which has been experimentally justified between somewhat wide but ill-defined limits.

6. *Coëfficient of sliding friction for glass and other tubes.*—Navier assumed that a flowing liquid would glide or slip with a finite velocity at its bounding surface,[1] and Piotrowski's experiments—by method (*d*) § 1—interpreted by Helmholtz,[2] confirmed this view to a limited extent, for although there was no slipping in the case of ether and alcohol in contact with polished gilt surfaces, with water and some other liquids slipping apparently occurred, and values for the coëfficient were deduced.[3] Piotrowski's experiments did not include cases of flow through tubes under pressure, but Helmholtz, after developing the theory of Piotrowski's method, turned his attention thereto, and deduced the formula to which we have already referred. He concluded from an examination of Girard's observations that sliding friction, the assumed existence of which seemed to explain Piotrowski's results, must also be postulated in the case of flow through tubes, at any rate when their dimensions were somewhat larger than those used by Poiseuille, and when they were of copper instead of glass. He further deduced a value for his coëfficient *b*—in our first equation—by applying the formula on the assumption that the motion might be deemed steady.[4]

The legitimacy of these conclusions was questioned by Whetham in 1890[5] who judged, from his experiments by an efflux method, that no slip occurs, at any rate in the case of surfaces which are wetted by the liquid.[6] But Brodmann—in 1892—has demonstrated, I think beyond doubt, that water in contact with a gilt surface does not adhere thereto and that under such circumstances

[1] Mém. de l'Académie, t. 6, p. 389.

[2] Sitzber. Akad. Wien., Bd. 40, p. 607 - 658.

[3] *Loc. cit.*, p. 621.

[4] Ibid, p. 656, where $\lambda = b$ in the equation previously given.

[5] On the alleged slipping at the boundary of a liquid in motion.—Phil. Trans., Vol. 181, p. 559.

[6] Ibid, p. 582.

slipping does occur, so that Whetham's conclusion must be restricted. That it occurs in cases of flow in glass tubes has certainly not been shown, but in regard to copper tubes the interpretation of Girard's experiments *seemed* to require that slipping be postulated,[2] and it is somewhat singular that a recent determination by Brodmann of the value of $\eta\,\beta$ for water by the sphere and cylinder methods gives a result[3] $\eta\,\beta = 0{\cdot}0409$—very nearly identical with Helmholtz's value[4] $= 0{\cdot}03984$—deduced from the efflux observations of Girard. On the other hand it has been pointed out by Jacobson that Helmholtz in criticising Girard's experiments failed to apply any correction to the pressure, and that his own—Jacobson's—experiments with copper tubes lend no support to the opinion that slipping occurs.[5] The general theory of flow in tubes being however beyond the scope of this discussion, it will suffice to show that Helmholtz's view is unsupported by experimental results in cases of steady rectilinear flow in glass tubes, such as are used in observations of efflux having for their object the determination of the viscosity.

If we put

$$\eta_b = \frac{\pi(p_0 - p_1)\,R^4}{8\,q\,L} \text{ and } a = 4\,b = 4\frac{\eta}{\beta}$$

then we shall have from (1), by transposition.

$$\eta = \eta_b\,(1 + \frac{a}{R})$$

the term a/R depending on the existence and influence of sliding friction, so that, if the viscosity be computed without reference thereto, we shall obtain the results η_b instead of η, and these will show a variation with widely different values of R, since a is constant.

From the results hereinafter quoted, obtained from Poiseuille's experiments on the assumption that slipping does *not* occur, we

[1] Wied. Annal. Bd. 45, p. 184.

[2] As against this view see Couette's memoir Annal. de Chimie, 6 Sér. t. 21, 1890, p. 492 - 494.

[3] Wied. Annal. Bd. 45, p. 179.

[4] Sitzber. Wien. Akad. Bd. 40, p. 656.

[5] Achiv. für Anat. u. Phys., 1861, p. 306.

take the mean values for Poiseuille's tubes the ratio of whose radii varies between the limits 1 and 47.

Glass Tubes.	Mean of.	R approx. c.m.	η_b at 10° C.	Authority.
$M\ M_1$	(2)	·0007	·01313	Poiseuille
$E\ E_1$	(2)	·0015	·01341	do.
$D-D_3$	(4)	·0022	·01305	do.
$C-C_3$	(4)	·0042	·01308	do.
$B-B_3$	(4)	·0056	·01310	do.
$A-A_3$	(4)	·0071	·01308	do.
$F-F_2$	(3)	·0326	·01315	do.

The constancy of η_b shows that it must be supposed identical with η, that is to say a is zero for cases of efflux through glass tubes, as indeed is admitted by Helmholtz.[1] Nor does a more extended comparison of values similarly deduced lead to a different conclusion. In the table hereunder tubes of different materials are included, and of larger radius, that of the greatest being 907 times that of tube M above.

Tube.	No. Expts.	R approx. c.m.	η_b at 10° C.	Authority.[2]
Glass	1	·0140	·01400	Hagenbach
,,		·0172	·01320	Grotrian
,,		·0182	·01318	,,
,,	2	·0198	·01311	König
,,	3	·0199	·01291	,,
,,	4	·0290	·01331	Slotte
Copper	2	·0297	·01356	Couette
Glass	4	·0302	·01319	Wagner
,,	1	·0309	·01400	Hagenbach
White metal	3	·0504	·01341	Couette
Glass	1	·0525	·01324	Hagenbach
,,	1	·0550	·01287	,,
Paraffine	3	·0685	·01360	Couette

[1] Sitzber. Wien. Acad. Bd. 40, p. 654.

[2] These values I have reduced from the data published by the investigator whose name is appended. The same remark applies to the preceding values obtained from Poiseuille's experiments.

Tube.	No. Expts.	R approx. c.m.	η_0 at 10° C.	Authority.
Glass	8	·0877	·01323	Jacobson
,,	5	·1147	·01334	,,
Brass	7	·1433	·01313	,,
Lead	8	·3075	·01360	Reynolds
,,	8	·6350	·01365	,,

These results give no indication of slip, for though the final value is somewhat larger than the mean, the difference is infinitesimal in relation to the supposed magnitude of the slip coefficient.[1]

It may be remarked that Coulomb's experiments also appeared to indicate an adhesion of the liquids to the submerged oscillating discs,[2] and that despite considerable alteration in the nature of the substances with which they were covered: so also did Meyer's.[3] But what is more to the point, is that when the motion is undoubtedly steady and rectilinear, all experiments by the efflux method with *glass* tubes—and it appears from the above that there is but a doubtful necessity even for this qualification—agree in negativing the idea of slip, not only in the case of water which wets the tube, but also in the case of mercury which does not. The observations of Warburg,[4] Villari,[5] and Koch[6] on the efflux of this latter substance, may be taken as determining the question of slip in regard thereto in the negative, and *a fortiori* in the case

[1] Taking the values for tube M and for the largest lead tube, in order to calculate the supposed slip, we would obtain for η_0 ·01365+ and for β, 1968. This is sensibly infinite as compared with its value in Helmholtz's deduction, for according to that authority η/β is ·03984, whereas the the above value of β would give only ·000007. Any variation of or progression in the several values of η may be otherwise accounted for. See § 22.

[2] Mém. l'Institut National, t. 3, p. 389.

[3] Ueber die Reibung der Flüssigkeiten.—Pogg. Annal., Bd. 113, p. 55 etc. 1861.

[4] Ueber den Ausfluss des Quecksilbers aus gläsernen Capillarröhren.—Pogg. Annal. Bd. 140, p. 367–379, 1870.

[5] Sull 'efflusso del mercurio per tubi di vetro di piccolo diametro.—Mem. dell 'Accad. d. Sci., Bologna, Ser. 3, t. 6, p. 1, 1876.

[6] Ueber die Abhängigkeit der Reibungsconstante des Quecksilbers von der Temperatur.—Wied. Annal. Bd. 14, p. 1–12, 1881.

of water. But apart from such theoretical deductions from experiments, it may be noticed that the strong adhesion of the bounding film to the tube was visually demonstrated in the experiments of Duclaux.[1] We may therefore in dealing with the theory of flow in glass capillary tubes, when the motion is rectilinear confidently assume that the coëfficient β in equation (1) is infinite—or in other words that there is no slip—that the velocity at the boundary of the section is consequently zero, and that the term in R^3 vanishes, and this assumption will generally be correct for any tube whatsoever for steady rectilinear flow.

7. *The reduced equation of flux.*—Denoting by P' the difference[2] $p_0 - p_1$, the original equation (1) becomes for zero velocity at the boundary

$$q = \frac{\pi P' R^4}{8 \eta L} \ldots\ldots\ldots\ldots\ldots\ldots (2).$$

a formula first given by Neumann, then by Jacobson, Hagenbach,[3] and Helmholtz. If K be substituted for $\pi (2^7 \eta)$ and D the diameter for R the radius, Poiseuille's formula[4]—

$$q = K \frac{P' D^4}{L},$$

derived experimentally about 1840, is obtained. The earlier formulæ viz. Girard's (1813), and Navier's (1822) were erroneous, making the efflux proportional to the third instead of the fourth power of the diameter.

8. *The determination of the fall in pressure.*—In large tubes, in which flow is established, the fall in pressure due to viscosity or other resistances between two cross sections any distance apart, may be measured manometrically, or by observing the vertical

---

[1] Recherches sur les lois des mouvements des liquides dans les espaces capillaires.—**Annal. de Chimie, 4 Sér. t. 25, 1872.**

[2] We use P instead of P as the latter is hereinafter used to denote a pressure directly observed but subject to certain corrections.

[3] Pogg. Annal. Bd. 109, p. 397, 400, 401. In our notation $\eta' = \eta/g$ is Hagenbach's k/n or z.

[4] Comptes Rendus, t. 11, p. 1046, 1840. Mém. des Savants étrang. t. 9, p. 519. The relations of K, P η for arbitrary or for absolute units are referred to hereafter: here we regard only the *form* of the expression.

height to which the liquid will rise in tubes attached normally to the surface of the pipe,[1] the connecting orifices being very small in relation to the sectional area of the flow. Such an arrangement cannot be realized with capillary tubes so that the fall in pressure must be deduced from measures of the pressures in the reservoirs supplying and receiving the flowing liquid. The sectional areas of these should be, and will be assumed to be, very large in relation to the sectional area of the capillary.

In Fig. 1, in which A denotes the supplying and B the receiving reservoir—*i.e.* the flow being supposed to take place in the direction A B—the points A and B lie in the axis of the tube EE' FF', supposed horizontal; to these points the measures of the pressures in the reservoirs are referred, P being the difference of those pressures. It is immediately evident from the principle of conservation of energy, that, neglecting losses from frictional resistances, the pressure at the section $e\,e'$ where the régime of parallelism of flow is established, is less than the pressure in the reservoir A, owing to the change from potential to kinetic energy in the effluent liquid. This was not overlooked either by Jacobson or by Hagenbach as already pointed out. The latter divided the head, or charge as it is often called, as measured by the difference of pressures, and expended in overcoming resistances, into two parts, the velocity-head (Geschwindigkeitshöhe) and the head due to frictional resistance within the tube (Widerstandshöhe). Hagenbach's formula[2] may be written, if we adopt an absolute notation, or *C.G.S.* units[3]

[1] This is usually called the piezometric measurement of the pressure by hydraulicians.

[2] Pogg. Annal. Bd. 109, p. 408, 1860.

[3] Using *C.G.S.* units we shall express P in dynes per square centimetre, thus $P = p\,g$, if p be the pressure in grammes per square centimetre, and g the acceleration of gravity in centimetres per second. The advantage of this treatment is that the derived value of η will be absolute, that is independent of the force of gravity. Its value must always be related to the unit of P, consequently if grammes per square centimetre be employed in expressing the pressures the correlative value of the viscosity η' may be referred to the above by the equation $\eta' = \eta\,g$. The absence of the g term in the quotation of Hagenbach's equation is thus explained.

$$\eta = \frac{2^{\frac{1}{3}}\,\pi^2 P R^4 - \rho q^2}{2^{\frac{10}{3}}\,\pi L q}$$

ρ being the absolute density —grammes per cubic centimetre—of the effluent. This will more clearly exhibit the reduction of the pressure if put in the form

$$\eta = \frac{\eta R^4}{8 L q}\left[P - \frac{\rho q^2}{2^{\frac{1}{3}}\,\pi^2 R^4} \right]$$

so that the term in brackets denotes, according to Hagenbach, what might be called the reduced pressure,[1] say P_0. Hagenbach justly observed that this correction more particularly applied where the end of the tube is in the form of a conoidal adjutage. Since we propose to consider the value of the coëfficient of the correction, the reduced pressure P_0 may with greater generality be written—

$$P_0 = P - m \frac{\rho q^2}{\pi^2 R^4} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3).$$

According therefore to Hagenbach the value of the factor m for a conoidal terminal is,

$$m = 2^{-\frac{1}{3}} = 0{\cdot}79370$$

Reynolds,[2] remarking that Poiseuille, though he measured the pressures in the vessels supplying and receiving the flowing liquid, nevertheless neglected the correction, states that, if U denote the mean velocity in the pipe and g the acceleration of gravity, it will be either $U^2\,(2g)$ or $1{\cdot}505\ U^2\,(2g)$ according as the entrance terminal of the tube is trumpet-shaped or cylindrical. He also says that, as Poiseuille definitely affirmed the latter condition to have been realized in his experiments,[3] the application of the correction would have made them consistent,[4] a dictum however

[1] It is hereinafter shown that P_0, may be generally supposed to be (as P in equation 2), but that this supposition may be set aside by specific evidences of its illegitimacy in particular cases.

[2] Phil. Trans., Vol. 174, p. 981, 1883.

[3] See Poiseuille's treatise, p. 430. La soudure est faite de telle sorte que la cavité du tube D (the capillary, se dilatant *en abrupto*, est en rapport avec du renflement G (a bulb at the end of the tube forming the reservoir of supply).

[4] *Loc. cit.*, p. 981.

which must be received with considerable limitation. Reynold's proposed correction is evidently based on the results of experiments with sharp-edged cylindrical adjutages of 2 or 3 diameters length applied to orifices, the effect of which is to cause a discharge of about 0·815 of that theoretically due to the pressure on the supposition that frictional and other resistances may be neglected. This loss of head, arising from the contraction[1] at the entrance of the adjutage, and the subsequent expansion to its full diameter, together with the loss from slight frictional resistance and that involved in establishing the flow, gives according to treatises on practical hydraulics $U^2/[2g\,(0{\cdot}815)^2] = 1{\cdot}506\,U^2/(2g)$. If the edges of the cylinder be rounded off at the connection with the discharging vessel at E', Fig. 1, the value becomes very nearly $U^2/(2g)$, the coëfficient 0·815 increasing almost to unity, according therefore to Reynolds, for the condition assumed by Hagenbach, $m = 0{\cdot}500$, or for the reduction of Poiseuille's work $m = 0{\cdot}753$. This statement is not justified by an analysis of the experiments referred to. The objection to unconditionally assuming that the square of the mean velocity in the section may be regarded as equivalent to the mean of the squares of the velocities at different points throughout the section, in estimating the loss of head necessary to establish flow, is obvious. Couette,[2] treating the problem more exactly, deduced for m the value unity, observing that it is just double that obtained by the application of Daniel Bernoulli's theorem, which attributed to all the molecules of the fluid a velocity equal to the mean velocity. He proposed therefore the more rigorous formula

$$P_0 = P - \frac{\rho\, q^2}{\pi^2 R^4}$$

This had been previously given under another form by Jacobson

[1] See Kirchhoff's Vorlesungen (22nd) for a solution in two dimensions. Bassett states in his treatise on Hydrodynamics, Vol. 1, p. 135. that no solution of the problem in three dimensions exists so far as he was aware in 1888. It was given by Boussinesq in 1872, see his "Essai sur la theorie des eaux courantes."—Mém. des Savants étrangers, t. 23, p. 562, 1877.

[2] Annal. de Chimie, 6 sér. t. 21, chap. iii., p. 494, 1890.

in September 1860, in his Introduction to Hæmodynamics, the development being credited, as I have previously said, to Neumann, whose formula may be written in our notation,[1] m however being assigned the value unity,

$$g\,h = m\,U^2 + \frac{8\,\eta\,L}{\rho\,R^2}\,U \ldots\ldots\ldots\ldots (3a).$$

h denoting the pressure at the entrance to the tube expressed as height of a column of liquid of the same density as the effluent, and U the mean velocity in the transverse section. Couette was evidently unacquainted with Neumann's or Jacobson's work, but in this respect he is not singular.[2]

Boussinesq[3] has attacked the problem with greater rigour, and —while admitting that Couette's solution, which is the same as Neumann's, is legitimately derived, and to a first approximation is accurate—shews that a higher approximation gives for m the value 1·12. Thus according to the several authorities mentioned,

$m = 0{\cdot}50$	Reynolds (after Bernoulli)	1883
$m = 0{\cdot}79$	Hagenbach	1860
$m = 1{\cdot}00$	Neumann prior to ...	1860
$m = 1{\cdot}00$	Couette	1890
$m = 1{\cdot}12$	Boussinesq	1891

Poiseuille's series of measurements, at different pressures and at 10° C., for a number of tubes afford a means of ascertaining the value of this coëfficient for each series: and it may be remarked that, *a priori*, one would expect the deduced values, if not identical with, to be somewhat greater than Boussinesq's coëfficient, inasmuch as it is said that the tubes retaining their cylindrical form

---

[1] Archiv. fur Anat. und Phys. Reichert's, 1861, p. 321. In the original formula both sides of this equation is multiplied by 2.

[2] That Hagenbach's correction should have been so invariably used, is in itself an indication of how little is generally known of Neumann's fine exposition of the theory of flow in a tube.

[3] Comptes Rendus, t. 110, p. 1160–1166, et p. 1238–1242, 1890. Ibid t. 113, p. 9–15 et p. 49 ect. 1891. Théorie du régime permanent graduellement varié qui se produit près de l'entrée évasée d'un tube fin où les filets d'un liquide qui s'y écoule n'ont pas encore acquis lour inégalités normales de vitesse, etc.

throughout, terminated abruptly, and in such cases the resistances are greater. Poiseuille in each series, measured the time necessary for a certain volume to flow at different pressures. If this volume be denoted by Q, and the total efflux time by T, q in the preceding formulæ—being the volume per unit of time—is equal to Q/T for each pressure. Hence m denoting general value of the coëfficient, *i.e.* 1·12 theoretically, and supposing that the value P_0 in (3) may be substituted for P' in (2), we obtain the following expression for the viscosity, viz.[1]

$$\eta = \frac{\pi R^4}{8 L q}\left(P - m\frac{\rho q^2}{\pi^2 R^4}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots(4).$$

In this formula Q/T may be substituted for q, that is we may write T in the numerator, and Q instead of q in the denominator, and in this way may obtain by transformation an expression for what may be called the corrected time of total efflux, viz.

$$T_0 = T - m\frac{\rho Q}{\pi^2 R^4 P}\cdot\frac{1}{T} = \frac{8 L Q \eta}{\pi R^4 P} \quad \ldots\ldots\ldots\ldots\ldots(5)^2$$

For a series of experiments at a uniform temperature with the one tube, the right hand member of (5) is a constant, and may be denoted therefore by C: thus we obtain the relations,

$$C = P_0 T = P T_0 = P T - m\frac{\rho Q^2}{\pi^2 R^4}\cdot\frac{1}{T} = \frac{8 L Q \eta}{\pi R^4} \quad \ldots\ldots\ldots\ldots(6).$$

A very large number of experiments have been corrected, as before stated, by means of the equivalent of formula (5), Hagenbach's value for m however being used. The time T_0 is the total efflux time, when the loss of head at the entrance to the tube divided by the product of the pressure into the time is negligible, and equation (6) shews that we may correct either the pressures, or the times. Reverting to Poiseuille's work, if the pressures in a series of observations made at a uniform temperature with the one tube, be multiplied by the corresponding times of efflux, the series of products PT is obtained, which, since the right hand member of (6) under the supposed conditions is a constant, differ only by the

[1] See also formula (40) § 21 hereinafter.

[2] For the calculation of T_0 when Q is unknown see § 21, formula (43).

corrective term whose factor is $1/T$, the other part being also a constant. Hence (6) may be written

$$C = PT - \frac{c}{T} \ldots\ldots\ldots\ldots\ldots\ldots (6a).$$

To determine C, the number must be found towards which PT approaches when T is increased without limit, and therefore P diminished without limit. The equation

$$PT = C + \frac{c}{T} \ldots\ldots\ldots\ldots\ldots\ldots (6b).$$

is that of a straight line, such that if the several values of $1/T$ be regarded as abscissæ and the corresponding values of PT as ordinates, the line passing through the points so determined will intersect the axis of ordinates at the distance C from the origin, and make with the axis of abscissæ an angle whose tangent is c. This value C corresponds to the value $1/T = 0$, or $T = \infty$, the corrective term therefore vanishing.[1] Fig. 2 shews the plot for Poiseuille's tubes A_5 A_7 B_5 and C_5. Should the products PT shew no progressive increase, as is sometimes the case,[2] no value can be assigned to c, nor consequently to m, for, when c is found, m is determined from (6) and (6a) by the equation

$$m = c\,\frac{\pi^2 R^4}{\rho Q^2} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

for absolute units. If the pressures be denoted by the lengths in centimetres of the columns of liquid in the manometers, h, it will be generally convenient to form the products $h\,T$ instead of $P\,T$. Let μ denote the density in grammes per cubic centimetre of the liquid in the manometers, and g the acceleration of gravity in centimetres per second, then from the relation

$$P = pg = \mu h g$$

we have from (6)

$$C' = hT - m\,\frac{\rho\,Q^2}{\mu\,g\,\pi^2 R^4} \cdot \frac{1}{T} = \frac{8\,L\,Q\,\eta}{\pi\,R^4\,\mu\,g} \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

and writing

$$hT = C' + \frac{c}{T} \ldots\ldots\ldots\ldots\ldots\ldots (8a)$$

---

[1] P also equals zero when $1/T = 0$, or $T = \infty$.

[2] The discrepancies of the members of the series may be, and often are, so great as to obliterate, as it were, all evidence of the progression.

in which therefore $c' = c_1'(\mu g)$, we obtain

$$m = c' \frac{\mu g \pi^2 R^4}{\rho Q^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

If the density of the liquid in the manometers (μ) be identical with that of the effluent liquid (ρ), μ/ρ will be unity.

By formula (8*a*) and (9), I have ascertained where possible, the values of m from Poiseuille's measurements with tubes A to F. Those given hereunder are derived from a combination of numerical and graphic methods. Through the points whose coördinates $l\ T$ and $P\ T$ were drived from Poiseuille's series, as for example, the series A_5, A_7, B_5, C_5, shewn in Fig. 2, a mean line was drawn. Two members of the series most nearly agreeing with this line were usually then selected and the values of c and C found by the formulæ[1]

$$c = \frac{P_2 T_2 - P_1 T_1}{\frac{1}{T_2} - \frac{1}{T_1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

$$C = P_1 T_1 - \frac{c}{T_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

When for each tube designated by the one letter as A_3, A_4, etc., c had been determined, its multiplication by the fractional factor in (9)—a constant for the tubes so designated—gave the values of m. The radius used was not the mean for the whole tube but the mean radius[2] at it entrance.

Values of m deduced from Poiseuille's experiments.

Tube.	Length c.m.	Radius c.m.	Values of m.	Tube.	Length c.m.	Radius c.m.	Values of m.
A_3	2·55	·00708	1·04	B_4	·39	·00567	1·03
A_4	1·57	,,	1·02	C_5	·60	·00427	1·87*
A_5	·95	,,	1·15	F_1	20·00	·03267	1·08
A_6	·68	,,	1·08	F_2	9·97	,,	1·33
A_7	·10	,,	1·12	F_3	5·04	,,	1·16
B	10·00	·00567	1·23	F_4	2·60	,,	0·82*
B_4	·90	,,	1·14	F_5	1·07	,,	0·82*
	Mean		1·14 : Mean rejecting C_5, F_4, F_5				1·13

[1] Actually h, c' and C' were used. Thus in (10) c' replaced c, and h, P. In (11) C', h and c' replaced C, P and c.

[2] By mean radius is meant here the mean proportional between the greatest and least radii. If the section be truly an ellipse the mean radius so defined will be that of a circle of equal area.

Tubes A_1 and A_2, B_1 to B_3, C to C_4, D_1 to D_4, E to E_2, and F give no satisfactory indication as to the value of this factor. For tubes A and D the following results were obtained, viz., 0·4 or 0·5, and 1·2, these values however are entitled to but little confidence inasmuch as they depend on lines the directions of which are determined by the positions of three points only, two of these being close together so far as the abscissæ are concerned, but in regard to the ordinates, not sufficiently concordant to warrant confidence. For tubes A_3 and B the results depend respectively on 2 and 3 points: in the other cases on from 7 to 10.

It is difficult to assign a reason for the values 0·82 for F_4 and F_5; possibly the flow was turbulent; the values for the viscosity —see the table hereafter—point to that. But one would have expected that A_7 would also have given similar indications, which it does not excepting for the last member of the series. The value is of course that for the fall of pressure known to occur in efflux through a short adjutage. The value for C_3 may perhaps be accounted for by the presence of a particle at the entrance of the tube interfering with the flow. The general result however agrees remarkably well with Boussinesq's deduction from kinetic theory, and since in the instances of some of the tubes showing discordant values the amounts of the corrections are much smaller than the discrepancies among the observations themselves, no doubt need be entertained as to the propriety of its application where there is no evidence of the particular value of m.

It may here be noticed that in illustrating his theory of the correction to the pressure Couette selects series A_4 and A_6 to exhibit the advantage of his formula over Hagenbach's[1]. For these tubes m is respectively 1·02 and 1·08. For the former the factor is sensibly unity and therefore the agreement with Couette's result is satisfactory; in regard to the latter the progressive increase of the corrected values of η is clearly a consequence of the fact, that the correction factor is too small. This leads me

[1] Annal. de Chimie, 6 sér. t. 21, p. 502, 1890.

to remark that this correction must be not only well ascertained but also small, for accurate measurements of viscosity, since there is ample evidence that it is variable in amount even under conditions where one would anticipate constancy. In illustration of this we take for data the results of several series of measurements of pressure-heads and velocities at constant temperatures made by Jacobson,[1] with his brass tube C, whose radius and lengths were respectively 0·14328, 62·04, and 15·76 c.m., and which was so fitted that its influx terminal was flush with the inner surface of the large reservoir which supplied the effluent.[2] For measurements of pressure-head and mean velocity we have, since $U = q/(\pi R^2)$

$$\frac{h}{U} = c'' + \frac{m}{g} U$$

in which $c'' = 8 L \eta / (\rho g R^2)$, and is therefore constant while the temperature is so. The value of m was found by the graphic method, the above being a linear equation.[3]

Values of m deduced from Jacobson's experiments.

No. of experiments in series	5	4	7	5	9
Deduced value of m ...	1·38	1·25	1·44	1·30	1·55

Another result from a series of five measurements with a tube of 0·12516 radius and 15·77 c.m. length,[4] was $m = 1·08$.

The fall in pressure at the entrance of the tube was also directly observed by Jacobson,[5] his experiments being made with a brass tube of 0·2545 radius and lengths as shewn, and the temperatures maintained constant for the measurements of any one series. The tube was bored through at a point 0·15 c.m. from its influx terminal[6] and the fall in pressure ascertained from the difference

[1] Archiv. für Anat. u. Phys., 1860, p. 93 and 1861 p. 327.

[2] Ibid. 1860, p. 83.

[3] Jacobson's coëfficient t. p. 94, said to be obtained from the observations by the method of least squares, should, when multiplied by 10 give values sensibly equal to these. They are nearly so.

[4] Ibid. 1861, p. 327. [5] Ibid. p. 309.

[6] It should be mentioned that the coëfficient t p. 322 of the 1861 volume, Archiv. f. Anat. &c., when multiplied by g and expressed in the C.G.S. units is our m, and that its values for Poiseuille's tubes, p. 326, are very nearly identical with those hereinbefore given.

in the height of the water in the reservoir, and in the manometer attached at the bore near the terminal. I have computed the coëfficient by the formula

$$m = \frac{g}{U^2}(h - h_0)$$

h being the height, above the axis of the tube, of the water in the reservoir, and h_0 that in the manometer: the derivation from formula (4) is evident.

Values of m deduced from Jacobson's measurements of the differences of pressure between the reservoir and within the tube near its entrance:

L =	134	71	71	212	101	101	242	212
m =	1·06	1·09	1·22	1·10	1·38	·91	·93	1·09
	·99	1·15	1·19	·94	1·28	1·00	·87	·96
	1·31		1·26	·94	1·54	·96	·79	·88
				·89	1·41			·82
				1·40	1·42			

The mean of these 28 results is 1·10, of these with the 6 preceding, 1·14; this average gives a general confirmation to Boussinesq's theory, but the individual results shew how, even under circumstances in which uniformity might be expected, it is not realized. The differences are certainly not due to mere errors of observation. We see therefore that Hagenbach's correction must be increased 41%, Couette's 12%, and that Reynolds' dictum is negatived: and further, that if this correction be of sensible magnitude, the deduced viscosity is to the extent of the uncertainty therein unreliable.[1]

9. *The correction to the length of the tube.*—In the preceding article it has been shewn how the product of the pressure and time of efflux of a given volume of fluid may be found, when the loss of head at the entrance of the tube vanishes or is eliminated. Following Hagenbach it has usually been assumed that this correction is the only one necessary, or that the corrected differences of pressures may be regarded as the differences at the terminals of the tubes; and Reynolds tacitly admits this view

when he affirms that the correction $1{\cdot}505\ U^2\ (2g)$ will make Poiseuille's experiments consistent. Clearly however the corrected pressure for the entrance of the tube gives the value, not for the section EE', but ee', Fig. 1, the distance between these, however being unknown, and probably somewhat uncertain as to constancy. It is however unlikely that it ever reaches two diameters where the end is sharply cylindrical or even one where it is conoidal or rounded off. Couette,[1] Boussinesq approving his view, with greater rigour takes into consideration the features of the flow not only at the entrance but also at the point of efflux from the tube. He recognises (a) that its length should be reduced for the distance between the sections EE' and ee'; (b) that frictional resistance is suffered by the liquid before it reaches this latter section—where parallelism of flow is fully established: (c) that the effluent liquid penetrates that in the receiving reservoir, and maintains for an appreciable distance its cylindrical form without sensible change[2]: (d) and that the surrounding liquid offers frictional resistance to this penetration by the effluent. If lengths of tube whose resistances are equal respectively to the resistances (b), and (d) above mentioned, be denoted by l_3 and l_4, and the distances $Ee = E'e'$ and $Ff = F'f'$ respectively by l_1 and l_2, the corrected length L_0 will be

$$L_0 = L - l_1 + l_2 + l_3 + l_4 \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Couette argues that the part of the 'charge' expended by frictional resistances in the vicinity of the extremities of a tube ought to be at least approximately proportional to the efflux, as is the case with regard to the tube generally, and he therefore expresses the consequent reduction of the pressure under the form $8\eta l/q\ (\pi R^4)$, so that l will denote the algebraical sum of the terms l_1 to l_4.[3] It is affirmed by Couette[4] that this quantity l may be assumed to be always positive: we shall shew however that it appears sometimes to be negative and therefore we consider its sign to be undeter-

[1] Annal. de Chimie, 6 sér. t. 21, chap. iii., p. 494.

[2] FF' to ff' Fig. 1.

[3] Ibid. p. 501.

[4] Ibid. p. 500.

mined in the general case. Let P'_0 denote the pressure corrected for these frictional resistances etc. at the terminals, then since $L_0 = L + l$, we obtain from (2)

$$\frac{\pi R^4 P'_0}{8 \eta q} = \frac{\pi R^4}{8 \eta q} (P_0 - \frac{8 \eta l q}{\pi R^4}) = L + l \ldots\ldots\ldots (12a)$$

l, as we have said being either positive or negative. Combining this result with (3) and (4) and remembering that l, a function of R, denotes a small length of tube producing an equivalent loss of pressure to that arising from the friction at the ends, at the same time taking account of the positions of sections ee' and ff', and therefore that it may legitimately be put under the form $l = n R$, the general formula for the evaluation of the viscosity may be expressed :—

$$\eta = \frac{\pi R^4}{8 q (L + n R)} (P - m \frac{\rho q^2}{\pi^2 R^4}) \ldots\ldots\ldots\ldots (13)$$

in which n may have a positive or negative value, since l may be positive or negative. P then in this formula, is the measured differences of pressure in the reservoirs, and L the actual length of the tube. It remains to ascertain whether n has a constant value as supposed, and if so what the value is.

Assuming that C has been found from P_0 reduced by (3), or from T_0 reduced as indicated in (5), or preferably perhaps by extrapolation of a series of measures (11), we have at once from (13)

$$\frac{\pi C R^4}{8 Q L} = \eta (1 + n \frac{R}{L}) \ldots\ldots\ldots\ldots (14)$$

or if C' be used instead of C the numerator of the left hand member will be $\pi \mu g C' R^4$. If now the values of R/L be regarded as abscissæ and those of the first member of this equation as ordinates, a line passing through the points so determined will intersect the axis of ordinates at the distance η from the origin, and this line will make an angle with the axis of abscissæ whose tangent divided by η is n, the required factor. The intercept on the axis of ordinates corresponds to the values $R = 0$, or $L = \infty$, *i.e.* for the condition when the correction for resistances at the terminals of the tube is infinitely small in relation to the resistance

of the tube itself. Fig. 3 illustrates the method applied to Poiseuille's series B and F, the former giving a negative and the latter a positive value for n, viz. about $-5{\cdot}2$ and $+11{\cdot}2$, these however, especially the latter,[1] being subject to considerable uncertainty, as is manifest from the figure. The opposition of the sign of n is very evident in the following values for the viscosity (η) computed without regard to the corrective term nR.

Tube.	$\frac{R}{L} \times 10^5$	(η)	Tube.	$\frac{R}{L} \times 10^5$	(η)
B	56	·013202	F	85	·013147
B_1	75	3134	F_1	163	3065
B_2	115	3070	F_2	326	3249
B_3	240	3002	F_3	646	3967
B_4	630	2742	F_4	1254	4891
B_5	1455	2193	F_5	3034	4851

These results challenge the propriety of Couette's statement that l may be always regarded as positive and taken as nearly three times the diameter of the tube.[2] His deduction seems to be entirely based upon the fact that the indications of Poiseuille's experiments with tubes A_4 and A_6, happen to be in fortuitous agreement with the results of his own ingenious method of simultaneous and equal flow through two tubes of equal radii, but of different lengths. In order to adequately test the question, we take the whole series of Poiseuille's experiments of flow at 10° C., indicated hereunder, reducing them rigorously by the formulæ given hereinafter for flow in tubes elliptical in section and conical longitudinally. Whenever possible the values of hT_0 were found by extrapolation: when that method could not be followed m was taken as 1·12 for the correction, and these instances are indicated by an asterisk in the table hereunder. The results, arranged according to increasing values of R/L, evidently afford no immediate indication of a collateral increase in the value of η. Dividing them therefore in parcels of eight, we obtain almost identical mean values for the viscosity, whereas if Couette's

[1] Rejecting F_5: see the figure.

[2] Ibid p. 504–505.

dictum that n is about 6, were justified these means ought certainly to show a progression.[1] We conclude therefore that no general value, unless it be zero, can be assigned to n as assumed by Couette, that his deduction has been based upon an insufficient number of observations: hence no correction should be applied to the length of a tube unless experiments therewith clearly indicate its propriety. One would perhaps be hardly justified in declaring that n is in reality always zero, for the theory of the correction is rational, and there are experimental indications of, at least, its occasional validity: nevertheless in the absence of specific evidence as to its sign and magnitude in particular instances, there is no alternative but to disregard it.

Viscosity of distilled water at 10° C. as determined from Poiseuille's experiments with glass tubes.

Tube.	Expts.	$\frac{R}{L} \times 10^5$	$R^4 \times 10^{10}$	Length.	η_{10}
D*	1 – 3	22	·24284	10·030	·013074
M*		37	·002367	1·850	3090
C*	1 – 3	42	3·2504	10·0325	3028
D_1*	1 – 3	44	·23377	5·0225	3020
B		56	10·235	10·005	3202
C_1*	1 – 2	57	3·2659	7·495	3071
E*	1 – 3	64	·04716	2·31	3242
A		70	24·941	10·05	3145
				Mean	·013109
B_1*	1 – 3	75	10·276	7·505	3134
F		85	11207·	38·3825	3147
C_2*	1 – 3	86	3·2980	4·97	3151
D_2*	1 – 3	87	·22787	2·5175	3078
A_1*	2 – 4	93	25·059	7·58	3109
B_2*	1 – 3	115	10·303	4·9375	3070
A_2*	1 – 3	139	25·183	5·11	3119
F_1		163	11187·	20·000	3065
				Mean	·013109

[3] We reject the last four as being uncertain in respect of the régime under which the flow took place.

Tube.	Expts.	$\frac{R}{L} \times 10^5$	$R^4 \times 10^{-3}$	Length.	η_{10}
E_1*	1 – 3	174	·04840	0·85	·013588
C_3*	1 – 3	175	3·3394	2·44	3092
D_3*	1 – 3	219	·22440	0·995	3045
B_3*	1 – 3	240	10·331	2·3575	3002
A_3		277	25·231	2·555	2946
F_2		326	11233·	9·9725	3249
C_4*	1 – 3	421	3·3394	1·015	2498
A_4		450	25·231	1·575	3343
				Mean	·013095
M_1*		558	·002367	0·125	3181
B_4		630	10·357	0·9000	2742
F_3		646	11290·	5·045	3967
D_4*	1 – 3	649	·22331	0·335	2652
E_2*	1 – 3	706	·04840	0·210	3222
C_5		709	3·3394	0·6025	2015
A_5		742	25·231	0·955	3515
A_6		1046	25·231	0·6775	3607
				Mean	·013113
F_4		1254	11316·	2·600	4891
B_5		1455	10·368	0·39	2193
F_5		3034	11316	1·075	4851
A_7		7088	25·231	0·1 ?	6980
				General mean, rejecting last four	·013107

NOTE.—For an explanation of these experiments see § 19.

10. *Flow in a right circular cylinder.*[1]—The formula for flow in a right circular cylinder may be readily deduced directly from Navier's equations for a viscous incompressible fluid by making one of the axes, X say, coincident with that of the pipe, and assuming that the motion of all particles is parallel thereto, the

[1] It will be assumed in this and the subsequent sections as far as § 19 that slipping does not occur: so that the deduced formula must be considered as applying only to glass tubes or to such as do not permit of slip. This condition of zero velocity at the boundary probably obtains in every instance of steady rectilinear flow through tubes or pipes.

other components of motion consequently becoming zero. The equation

$$\rho\,(X - \frac{du}{dt}) - \frac{dp}{dx} + \eta\,\nabla^2 u = 0 \ldots\ldots\ldots\ldots (a).$$

with similar expressions in Y, y, v, and Z, z, w,—in which ∇^2 denotes as usual Laplace's operator, ρ the density of the fluid, X etc., the components of the external impressed forces per unit of mass and u, v, w the components of velocity in the directions x, y, z—reduce under the circumstances indicated to one, viz. that above written. The condition of the conservation of volumes or the equation of continuity becomes $du/dx = 0$, and that of steady motion is $du/dt = 0$. In a circular section u is clearly a function of r and t only: using therefore cylindrical coördinates, in which case the operator, thus restricted, becomes

$$\nabla^2 = \frac{d^2}{dr^2} + \frac{1}{r} \cdot \frac{d}{dr}$$

we have, neglecting external impressed forces,

$$\frac{1}{\eta} \cdot \frac{dp}{dx} = \frac{d^2 u}{dr^2} + \frac{1}{r} \cdot \frac{du}{dr}$$

The left hand side of this equation does not involve r nor the right hand x, hence each must be a constant,—A say. If therefore the difference of pressure in two sections the distance L apart be P, the left hand side of this last equation gives

$$\frac{1}{\eta} \cdot \frac{P}{L} = -A$$

and the right hand side

$$u = \tfrac{1}{4} A r^2 + B' \log r + C'$$

B' and C' being arbitrary constants, As the velocity at the centre of the pipe where $r = 0$, is finite, B' must be zero: substituting therefore the above value of A in the expression for u, and remembering in regard to the constant C' that when $r = R$, the radius of the pipe, $u = 0$, there being no slip at the boundary, we have for the velocity at any point in the section at the distance r from its centre

$$u = \frac{1}{4\eta} \cdot \frac{P}{L}(R^2 - r^2) \ldots\ldots\ldots (15)$$

From this (2) is obtained by substituting the value of u in the

expression for the total flux q across the section and integrating thus,[1]—

$$q = 2\pi \int_0^R urdr = \frac{\pi P R^4}{8 \eta L}$$

The expression for the mean velocity U in the section is found by dividing that for the total flux by the sectional area $S = \pi R^2$, thus

$$U = \frac{q}{S} = \frac{1}{8\eta} \cdot \frac{P}{L} R^2 \ldots\ldots\ldots (16)$$

For this régime therefore the resistance to flow varies as $1/R^2$

11. *Flow in an elliptical cylinder.*—Capillary tubes have usually been assumed to be right circular cylinders, and their radii have been determined on that assumption by filling definite lengths with mercury, ascertaining its weight, and from the weights the volumes of the cylinders. Poiseuille however did not rely on this method but made direct measurements. Discs of about 0·1 millimetre in thickness cut from the tubes, and prepared by grinding and polishing, were mounted with Canada balsam between plates of glass.[2] Under the microscope the contour of the cavity of the tube appeared as a slightly opaque line, permitting the measurement of diameters. In thirty-four sections thus prepared only one instance is recorded of uniform diameter, the greatest difference of diameters being an instance in which their ratio was $1\frac{1}{8}$ to 1—Tube F. On the supposition that the sections were ellipses Poiseuille used the mean proportional of the diameters —*i.e.*, the diameter of a circle of equal area— as the equivalent mean. As however the mean velocity varies as the square of the diameter, see (16), this procedure, it is easy to see, will be inexact when the ellipse differs sensibly from a circle. We proceed therefore to determine the equation of the flow in an elliptical cylinder.

[1] This development is that of ordinary treatises or hydrodynamics cleared of the irrelevancy as to a boundary condition apparently never realized, at any rate with glass tubes: q is of course the *volume* of the flow across a section, in a unit of time.

[2] Mém. des Savants étrangers, t. 9, p. 456 et 457.

Navier's equations (a) give for the flow in any cylinder—all motion being parallel to its axis, X say,

$$\frac{d^2u}{dy^2} + \frac{d^2u}{dz^2} = \frac{1}{\eta} \cdot \frac{dp}{dx} = 0 \ldots\ldots\ldots(b)$$

If as before we put

$$A = -\frac{1}{\eta} \cdot \frac{dp}{dx} = \frac{1}{\eta} \frac{P}{L}$$

and write

$$u = \phi - \frac{A}{4}(y^2 + z^2) \ldots\ldots\ldots(c)$$

we shall have, for all points in the section, Laplace's equation

$$\frac{d^2\phi}{dy^2} + \frac{d^2\phi}{dz^2} = 0$$

the solution of which is

$$\phi = F(y + \iota z) + f(y - \iota z) + C' \ldots\ldots\ldots(d)$$

If there be no slipping, the boundary condition $u = 0$ is determined by (c); hence, if we assume that in (d) each function F, f is the square,[1] these two equations give for the boundary of the section

$$M(y^2 - z^2) - \frac{A}{4}(y^2 + z^2) + C' = 0 \ldots\ldots\ldots(e)$$

in which M and C' are undetermined constants. If we further suppose the boundary to be an ellipse whose semiaxes are B and C the remaining condition to be satisfied thereat is therefore

$$\frac{y^2}{B^2} + \frac{z^2}{C^2} = 1$$

and these two equations completely determine the values of M and C', the solution giving

$$M = \frac{A}{4} \cdot \frac{B^2 - C^2}{B^2 + C^2}\ ;\ C' = \frac{A}{2} \cdot \frac{B^2 C^2}{B^2 + C^2}$$

Substituting these values in (e) and writing u instead of 0 we obtain

$$u = \frac{A}{2} \cdot \frac{B^2 C^2}{B^2 + C^2} \left\{ 1 - \left(\frac{y^2}{B^2} + \frac{z^2}{C^2} \right) \right\} \ldots\ldots\ldots(17)$$

The curves of equal velocity are homothetic ellipses, and the velocities are the same for homologous points on the radii vectores.

[1] This is equivalent to supposing that $\phi = My^2 + Nz^2 + C$: but Laplace's equation requires that $N = -M$, therefore $\phi = M(y^2 - z^2) + C$.

The integral for the total flux across the section is therefore

$$2\pi\frac{C}{B}\int_0^B uy\,dy$$

in which u must be written as in (17) omitting the term in ϵ^2. Making this substitution, writing $P/(\eta L)$ for A, and integrating, we obtain

$$q=\frac{\pi}{4\eta}\cdot\frac{P}{L}\cdot\frac{B^3C^3}{B^2+C^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(18)$$

so that if we put

$$R_0=\left(\frac{2\,B^3\,C^3}{B^2+C^2}\right)^{\frac{1}{4}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(19)$$

R_0 will be the radius of a circular cylindrical pipe of equal efflux. From (18), since $S=\pi BC$ we obtain for the mean velocity in the section

$$U=\frac{1}{4\eta}\cdot\frac{P}{L}\cdot\frac{B^2C^2}{B^2+C^2} \quad \ldots\ldots\ldots(20)$$

The radius R'_0 of a circular cylindrical pipe of equal mean velocity is therefore

$$R'_0=\frac{BC}{\sqrt{\left\{\frac{1}{2}(B^2+C^2)\right\}}} \quad \ldots\ldots\ldots\ldots\ldots(21)$$

When $B=C$ these formulæ become identical with those for right circular cylinders, viz. (2) and (16). Poiseuille tacitly assumed that $R_0=R'_0=\sqrt{(BC)}$. The error of this is best seen by reëxpressing (18) in the form of a series,[1] and comparing the result with B^2C^2 similarly developed. Putting

$$R_e=\tfrac{1}{2}(B+C) \text{ and } \epsilon=\frac{B-C}{B+C}$$

(18) may be recast in the form

$$q=\frac{\pi P R_e^4}{8\eta L}(1-4\epsilon^2+7\epsilon^4-8\epsilon^6+\ldots) \quad \ldots\ldots\ldots\ldots(18a)$$

If the radius of the circle of equal area be used, we have

$$B^2C^2=R_e^4(1-2\epsilon^2+\epsilon^4)$$

The difference in relation to the degree of precision to which Poiseuille has expressed his results is sometimes appreciable. For example in the case of the tube F, assuming the difference of

[1] This gives also a practically useful formula for computations.

semidiameters to be 1/16 and their sum to be 17/16, ϵ will be 1/17, hence the correction on Poiseuille's value will be $-2\epsilon^2 + 6\epsilon^4 - \text{etc.}$ = 0·00685 or about 1/146.

12. *Flow in a frustum of a right circular cone.*—Not one of the tubes used by Poiseuille was exactly a right circular cylinder, and the assumption of a cylindrical form is doubtless always unsafe, for capillary tubes are probably always more or less irregular in section. We proceed to consider the law of flow in a frustum of a right circular cone whose generatrix is nearly parallel to its axis, and more generally in a tube forming a series of conical frusta.

Since the motion of all stream lines is sensibly parallel—in the case supposed—to the axis of the cone, it will be necessary to have regard only to the variation of velocity with change in the area of the right section, and thus to determine the fall in pressure in terms of the radii of the tubes. Let R, R_m, R_n denote respectively the radius of the tube at the terminal of efflux, and proceeding toward the point of influx, the radii of the terminals of any conical length of the tube; and let also R_x denote the radius of a right section of this conical length at the distance x from R_m, x being measured therefore toward to point of influx, *i.e.* towards R_n. Then if U be the the mean velocity at the efflux terminal of the tube, the radius there being R, the mean velocity U_x at the transverse section whose radius is R_x will be

$$U_x = U\frac{R^2}{R_x^2} = \frac{q}{\pi}\cdot\frac{1}{(R_m + kx)^2} \qquad \ldots\ldots\ldots\ldots(22)$$

in which k denotes the tangent of the angle between the axis and side of the cone, may be positive or negative, and is expressed by the equation

$$k = \frac{R_n - R_m}{L_n} \qquad \ldots\ldots\ldots\ldots(f)$$

L_n being the distance between the terminal sections of the frustum under consideration. Equation (16) gives at once

$$U_x = -\frac{dp}{dx}\cdot\frac{R_x^2}{8\eta}$$

so that substituting for U_x its value by (22), and for R_x^2 its

equivalent in terms of R_m, k and x, we have for P_n, the difference of pressures at R_m and R_n

$$P_n = \frac{8\eta q}{\pi}\int_0^{L_n}(R_m + kx)^{-4}dx$$

Remembering that for $x = L_n$, $R_m + kx = R_n$, this gives by integration and reduction

$$P_n = \frac{8\eta q}{\pi}\cdot\frac{L_n(R_m^2 + R_m R_n + R_n^2)}{3R_m^3 R_n^3} = \frac{8\eta q}{\pi^2}\cdot\frac{V_n}{R_m^3 R_n^3} \quad \ldots\ldots(23)$$

V_n being the volume of the frustum; and similarly for any other length of the tube. The formula for a tube forming a series of conical frusta may consequently be written—

$$P = P_1 + \ldots\ldots + P_n = \frac{8\eta q}{\pi^2}\left(\frac{V_1}{R^3 R_1^3} + \ldots\ldots + \frac{V_n}{R_m^3 R_n^3}\right) \ldots\ldots(24)$$

If the quantity in brackets be divided by πL, L being the total length of the tube, it will give the reciprocal of the fourth power of the radius, say R^4, of a right circular cylinder of equal length and efflux, hence R may be called the 'mean radius of efflux' of the tube. This value is different to that used by Poiseuille, who neglecting variations of diameter between the terminals of the tubes, adopted for this mean radius $\frac{1}{2}(R + R_n)$.[1] The error of Poiseuille's value is best shown by expressing (23) in the form of a series, which form is also more convenient for the purposes of computation. Putting

$$R = \tfrac{1}{2}(R_n - R_m) \text{ and } e = \frac{R_n - R_m}{R_n + R_m}$$

(23) may be reëxpressed

$$P_n = \frac{8\eta q L_n}{\pi R^4(1 - \frac{1}{3}e^2 + \frac{7}{9}e^4 - \ldots)} = \frac{8\eta q L_n}{\pi R^4}(1 + \tfrac{1}{3}e^2 + 7e^4 + \ldots) \quad (23a)$$

The former of these is the more convenient expression for radii comparisons. The greatest value of e for any of Poiseuille's tubes is about 1·60—tube D: this produces an error of about 1·10⁻⁸⁰ if Poiseuille's method of reduction be followed.

13. *Flow in a frustum of a right elliptical cone.*—The departure from a circular form in the transverse section of capillaries is

[1] Excepting the case of the tube F, see p. 484 of his memoir.

doubtless frequently sensible: it has already been pointed out—§ 11—that in those used by Poiseuille only one instance occurred of uniform diameter. We proceed therefore to consider the flow in a frustum of right elliptical cone.

The general considerations are identical with those of the preceding article. To determine the velocity for any section we substitute in (22) $B\,C/(B_x\,C_x)$ for R^2 $(R_x^2$: hence taking account of the law of velocity expressed by (20), or otherwise directly from (18), we have

$$\frac{dp}{dx} = \frac{4\eta q}{\pi} \cdot \frac{B_x^2 + C_x^2}{B_x^3 C_x^3} \quad \ldots\ldots\ldots\ldots\ldots(g)$$

The ratio of B and C will be the same for every section, let therefore

$$\mathfrak{R} = \tfrac{1}{2}(B+C) \text{ and } \epsilon = \frac{B-C}{B+C}$$

(g) then becomes

$$\frac{dp}{dx} = \frac{8\eta q}{\pi \mathfrak{R}_x^4} \cdot \frac{1+\epsilon^2}{(1-\epsilon^2)^3}$$

$\mathfrak{R}$ being the only variable in the right hand member. The solution of this is identical with (23), hence we write at once

$$P_n = \frac{8\eta q}{\pi} \cdot \frac{L_n(\mathfrak{R}_m^2 + \mathfrak{R}_m\mathfrak{R}_n + \mathfrak{R}_n^2)}{3\,\mathfrak{R}_m^3\mathfrak{R}_n^3} \cdot \frac{1+\epsilon^2}{(1-\epsilon^2)^3} \quad \ldots\ldots\ldots\ldots\ldots(25)$$

The value of the ϵ term is

$$1 + 4\epsilon^2 + 9\epsilon^4 + \cdots = \frac{1}{1 - 4\epsilon^2 + 7\epsilon^4 \ldots}$$

This last equation may be expressed similarly to (23) since

$$V_n = \frac{\pi L_n}{3}(\mathfrak{R}_m^2 + \mathfrak{R}_m\mathfrak{R}_n + \mathfrak{R}_n^2)\ (1-\epsilon^2)$$

thus

$$P_n = \frac{8\eta q}{\pi^2} \cdot \frac{V_n}{\mathfrak{B}_m^3\mathfrak{B}_n^3} \cdot \frac{1+\epsilon^2}{(1-\epsilon^2)^4} \quad \ldots\ldots\ldots\ldots\ldots(25a)$$

The expansion of the final factor is

$$1 + 5\epsilon^2 + 14\epsilon^4 + \cdots = \frac{1}{1 - 5\epsilon^2 + 11\epsilon^4 \ldots}$$

The volume V_n may be found by filling the tube say with mercury. The practical application of the formula is obvious.

14. *Flow in a tube whose right section is an ellipse varying in excentricity and area.*—We now consider the case where the sections of a tube are ellipses or very approximately so, the ellipses being however dissimilar. The dimensions of the semiaxes for any two sections do not, unless we know how the surface is generated, determine the form or area of those intermediate: consequently in regard to these some assumption must be made. We may suppose that the terminal ellipses are similarly situated throughout,[1] and that straight lines joining the extremities of their axes lie wholly on the surface, every section notwithstanding being sensibly an ellipse. Hence we may put

$$B_x = B_m + k\,x \text{ and } C_x = C_m + k'x$$

k and k' being found similarly to (f) § 12 substituting respectively B and C for R in that equation. Then from (g) in the preceding article we have

$$P_n = \frac{4\,\eta\,q}{\pi}\left\{\int_0^{L_n}\frac{d\,x}{(B_m+k\,x)\,(C_m+k'x)^3}+\int_0^{L_n}\frac{d\,x}{(B_m+k\,x)^3\,(C+k'x)}\right\}$$

The integration of this expression by the usual method of decomposition[2] leads to unsuitable formulæ. It will be necessary therefore to adopt some value as a mean radius and express the result in a series of corrective terms, whose magnitude depends on the variation from the form of a right circular cylinder. Let

$$R_m = \tfrac{1}{4}\,(B_1 + C_1 + B_2 + C_2)$$

$$f = \frac{(B_1 - C_1)+(B_2 - C_2)}{4\,R_m}$$

$$b = \frac{B_2 - B_1}{2\,R_m} \qquad \text{and} \qquad c = \frac{C_2 - C_1}{R_m}$$

The integration then leads to the following expression

$$P_m = \frac{8\,\eta\,q\,L_m}{\pi\,R_m^4}\,(1 + 4\,f^2 + \ldots + \tfrac{3}{8}\,b^2 + 2\,b\,c + \tfrac{3}{8}\,c^2 - \ldots) \ldots\ldots\ldots (26).$$

The f, b, and c terms are obviously small. If their sum be denoted by $1+\xi$ then instead of writing this quantity in the

---

[1] If they be not similarly situated the formulæ are less rigorous: the correction for a slow rotation of the axes is probably quite insensible.

[2] The integration by the usual procedure for rational fractions gives formulæ which are indeterminate in the limiting case, *i.e.* when the ellipses become circles.

numerator it may be put in the denominator in the form $1-\xi$. The general 'mean radius of efflux' R is of course determined by the equation

$$\frac{L}{R^4} = \Sigma\left(\frac{L_m}{R_m}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots(27).$$

15. *Flow in a tube whose sections are ovals of unequal area and uncertain contour.*—Owing to its actual irregularities of form perhaps the theoretically least exceptionable method of determining the volume of a capillary tube and its mean radius of efflux, is to measure the former directly and compute the latter from measurements of the greatest and least diameters of its sections. The volume furnishes at once the radius of an equal right circular cylinder, and this radius may then be corrected so as to give the 'mean radius of efflux,' the corrections involving terms depending only upon the excentricities of the sections, and being therefore small.

If in formula (25*a*) § 13 we put[1]

$$R_m = \tfrac{1}{2}\,(\mathfrak{R}_m + \mathfrak{R}_n) \text{ and } \rho = \frac{\mathfrak{R}_n - \mathfrak{R}_m}{\mathfrak{L}_n + \mathfrak{L}_m}$$

we may write

$$\mathfrak{R}_m^3\,\mathfrak{R}_n^3 = R_m^6\,(1-\rho^2)^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots(h)$$

If now the excentricity of the terminal sections be nearly the same, or since we do not assume that the sections are ellipses if the ratio of the minor to the major axes be nearly equal for both sections, we may put

$$\epsilon^2 = \tfrac{1}{2}\,(\epsilon_m^2 + \epsilon_n^2)$$

The square of the radius R_v of a right circular cylinder of equal volume will then be

$$R_v^2 = \frac{V}{\pi L} = R_m^2\left(1+\frac{\rho^2}{3}\right)(1-\epsilon^2)$$

with sufficient precision. This last equation enables us to replace R_m by R_v, that is by the radius determined from actual measurement of the capacity of the tube. After some reduction and

[1] R_m in this formula has of course the same value as in (26) in the preceding section and $\rho = \frac{1}{2}\,(b+c)$.

rejection of terms in ρ and ϵ higher than the square, we obtain

$$P_n = \frac{8\eta q}{\pi} \cdot \frac{L_n}{R_v^4}(1 + 2\epsilon^2 + 4\rho^2) \text{ approx.} \ldots\ldots\ldots(28)$$

which may be used whenever ϵ^4 and ρ^4 are negligible. This limitation is not so serious as might at first appear, for one would select for the purposes of a viscosity experiment a tube closely approximating in form the right circular cylinder, or, if an oval and conical tube must perforce be used, one would be chosen in which the ratio of the axes was subject only to slight variation, and in which the axes themselves were of nearly constant magnitude throughout its length.

The fall in pressure may also be approximately expressed in terms of the mean of the diameters by substituting the value of R_v^4 in terms of R_m^4. This gives

$$P_n = \frac{8\eta q}{\pi} \cdot \frac{L_n}{R_m^4}(1 + 3\epsilon^2 + \tfrac{15}{8}\rho^2) \ldots\ldots\ldots\ldots(29)$$

If the ϵ and ρ terms be written in the denominator they must have the negative sign. This formula will sometimes serve as a rough check on (26).

16. *General result.*—The equations of Sections 10 to 15 not only supply the requisite mathematical material for an accurate computation of the viscosity from experimental data, but they furnish also ready means of estimating the consequence of any observed or hypothetical defect of form in a tube proposed to be employed for that purpose. And at the same time they indicate that the method of measuring the mean radius of capillaries only by contained volumes of liquid, is unsatisfactory when an accurate determination is required, for if the tubes be even slightly elliptical in section, or conical longitudinally, the volume of efflux per unit of time may sensibly differ from that of a right circular of equal length and volume. The degree of precision with which the 'mean radius of efflux' must be ascertained will always be four times as great as that required in the deduced viscosity, that is to say, if the latter is to be exact to say 1 in 1000, the mean radius must be accurate to 1 in 4000. For, if we put ξ for the ratio of

the uncertainty in the value of R, so that the radius is $R(1 \pm \xi)$, we have

$$\{R(1 \pm \xi)\}^4 = R^4(1 \pm 4\xi + \ldots)$$

The other elements in a measurement are involved only to the first power, and therefore their determinations need be only to one fourth the precision of that required in the case of the radius, perhaps the most difficult of them all to accurately measure.

III.—Determination of the Viscosity.

17.—*General—Units.*—C.G.S. units have been used throughout, and the viscosity is expressed in absolute measure, *i.e.* it is related to pressures expressed in dynes per square centimetre.

Density of Water—The relative densities of water are derived from Mendelejeff's table based on his formula[1]

$$\rho_\tau = 1 - \frac{(\tau - 4)^2}{(94{\cdot}1 + \tau)\,(703{\cdot}51 - \tau)1{\cdot}9} \quad \ldots\ldots\ldots\ldots(30)$$

ρ_τ denoting the relative density at the temperature τ centigrade. The absolute density at 4° C. has been taken as 1·000013 grammes per cubic centimetre.

Density of Mercury[2]—The density has been computed on the assumption that its value at 0° C. relative to water at 4° C. is 13·5956, and its absolute density at 0 —grammes per cubic centimetre—therefore 13·5958. The density at other temperatures has been derived through Broch's value for the coëfficient λ of total cubic dilatation, viz.

$$\lambda = (181808 + 0{\cdot}175\,\tau + 0{\cdot}035125\,\tau^2)\,10^{-9} \quad \ldots\ldots\ldots\ldots(31)$$

τ being the temperature in Regnault degrees[3] *i.e.* the 1/100 part of the expansion 0° to 100° C. The volume for the temperature

---

[1] Journal Russian Physical and Chemical Society, No. 5, 1891.

[2] For information concerning the density of mercury at 0° C. see Traité pratique de la thermométrie de précision : par Ch. Ed. Guillaume, p. 36, 37. Paris 1889.

[3] See the Travaux et Mémoires du Bureau International des Poids et Mesures, t. 2, p. 20. The expansions 0° to 100° C. are according to the following authorities Bosscha ·018241, Wüllner ·018253, Levy ·018207; the above coëfficients give ·018217.

τ, that at 0° being unity, is therefore simply $1 + \tau\chi$. For the air thermometer the coëfficients are respectively 181792, 0·175, and 0·035116, according to the same authority.

Dilatation of Glass.—Poiseuille adopted[1] for the coëfficient of cubic dilatation for glass, ξ, Dulong and Petit's estimate viz.,

$$\xi = 0{\cdot}0000258 \ldots\ldots\ldots\ldots\ldots\ldots (32)$$

to which, though somewhat less than later determinations,[2] I have nevertheless adhered as being sufficiently exact for the purpose in hand.

Thermometry.—The degree of rigour in the thermometric element of the various measurements of viscosity has not been explicitly indicated by each observer. Most of the measurements however are to an order of precision which rendered this of little moment. In the future it is to be hoped that rigorous methods of thermometry will be employed[3] and that the determination will be carried to a higher degree of precision: merely verificatory measurements are of little value at the present stage of the investigation.

18. *Poiseuille's experiments 1846. Volumes of the efflux.*—The volume discharged in a given time was measured by the content of bulbs, such as that shewn in Fig. 4, in which V denotes the bulb. These were filled with mercury and weighed with a precision of about 0·5 milligramme,[4] the temperatures being recorded. The results were then reduced so as to express the volumes at 10° C. Poiseuille assumed the density of mercury at 11°.5 —the temperature of one of the experiments, vide p. 515 of his memoir—to be 13·569675. By the constants used by me this should be 13·5674.

[1] Mém. des Sav. étrang. t. 9, p. 515 et 526, 1846.

[2] For the cubic dilatation of glass 0° – 100° C. Rossetti and Levy give ·0000262, ·0000267, and the mean of Regnault, Wüllner, and Levy's values is ·0000269: see Pogg. Annal. Ergbd. 5, p. 529, 1871.

[3] Such for example as are developed in Dr. Guillaume's Traité pratique de la thermométrie de precision, Paris, 1889; an indispensable work to the practical physicist in matters relating to thermometry.

[4] Mém. des Sav. étrang., t. 9, § 117, p. 515.

The volumes given by Poiseuille have therefore been multiplied by the factor 13·5697/13·5674 = 1·00017.

Pressures.—Pressures under 15 centimetres of mercury or 200 centimetres of water were measured by a water-manometer, those above that amount by a mercury-manometer.[1] The relative density of mercury to water at 10° C. was assumed by Poiseuille to be 13·576981.[2] I have taken it as 13·5746, and since the effect is to make Poiseuille's pressures under 15 centimetres too small, have multiplied them by the factor 13·5770, 13·5746 = 1·00017. In the case of tube *F* the uncertainty of the times of efflux is relatively so large that the application of this correction would be futile.

The acceleration of gravity for the place where Poiseuille made his experiments is given by him as 980·8 centimetres per second.[3] Taking the absolute density of mercury at 10° C. to be 13·5711, and of water to be 0·99975, we get for the absolute pressures *P*, by multiplying these numbers into the value of the acceleration

$$P = 13310{\cdot}5\ h_m = 980{\cdot}55\ h_w \quad \ldots\ldots\ldots\ldots\ldots\ldots (33)$$

h_m being the pressure expressed in centimetres of mercury, and h_w in centimetres of water, both at 10° C.

Dimensions of tubes and bulbs at different temperatures.—The dimensions of the tubes and bulbs used by Poiseuille were evalued for the temperature 10° C.[4] Four of the tubes were tested by filling with mercury and finding the area of the section from the volume.[5] The results were then compared with the direct measurements of the diameters of the sections, on the assumption that their contours were ellipses, for it is on this assumption and from the direct measurement alone that the dimensions of the tubes, may be found. In the illustrative case given by Poiseuille

[1] *Loc. cit.*, p. 460 (note), and § 65, p. 484.

[2] Ibid. p. 448–452: table 11, p. 475; and § 16, p. 532.

[3] Ibid. p. 531.

[4] This is explicitly stated by Poiseuille, vide § 83, p. 497 of his memoir: see also § 32, p. 457.

[5] Ibid, § 32, p. 457.

the volume method gave for the diameter of a circle of equal area ·00376 c.m., while direct measurement and the assumption of an elliptical contour gave ·00377. The difference 1/376 is small but by no means insensible, for since the diameter is raised to the fourth power this difference will lead to an error of 1/94 in the deduced value of the viscosity.

Computation of mean radius of efflux.—Poiseuille used for the mean radius the half sum of the geometrical means of the terminal radii.[1] But it has been shewn in § 11—formulæ (18) and (18*a*)—that the geometrical mean is too great, and in § 12 and § 15—formulæ (23*a*) and (29) that the mean of the terminal means is also too great. I have computed the 'mean radius of efflux' by the principle of formula (24) using formula (26) and occasionally checking by (29). With regard to the neglect of small terms in the computation &c., the condition has always been secured that the error shall be small in relation to the probable uncertainty in the data.

Dimensions of the tubes.—Poiseuille measured the lengths of the tubes used by him by means of a beam compass[2]—compas à verges—reading by a vernier to ·005 c.m. and permitting, by estimation, a record to half this amount.

When a series of efflux experiments with a given length of tube was completed, a portion of the free end was cut off by means of a file,[3] a procedure that was several times repeated. This permitted the measurement of transverse sections at different distances along the axis, and the regularity of these gave a general indication of the symmetry of the tube. The measurements of each section are taken in account by me in the computation of the 'mean radius of efflux.'

Effect of temperature on dimensions.—When, as was the case in Poiseuille's experiments, the whole of the reservoir of supply—the bulb *V* Fig. 4—the flowing liquid, and the capillary are maintained at the one temperature by immersion in a bath, or otherwise,

[1] Ibid. § 114, p. 513. [2] Ibid. § 83, p. 497. [3] Ibid.

no correction is necessary for temperature, so far as the dimensions of the apparatus are concerned, assuming that their original evaluations are all for the one temperature. This is evident if we consider the effect on the elements of the fundamental formula (4). For supposing the factor $(1+\zeta)$ to express the linear correction for expansion for the particular temperature to which all the parts are subject, then, on substituting for η its equivalent Q/T, we shall have[1]

$$\eta = \frac{\pi R^4 (1+\zeta)^4 P_0 T}{8 L (1+\zeta) Q (1+\zeta)^3} = \frac{\pi R^4 P_0 T}{8 L Q} \quad \ldots\ldots\ldots\ldots(34)$$

This indicates the desirableness of securing this condition.

Evaluation of the viscosity at 10° C. from Poiseuille's experiments. —The results of the computations for the values of the viscosity at 10° C. are given in the table in § 9. It is worthy of remark that the satisfactory determinations depend on tubes whose radii and lengths range between somewhat wide limits, viz.,

$R = 0{\cdot}0006975 \quad L = 0{\cdot}125$ c.m. Tube M_1
$R = 0{\cdot}032537 \quad L = 38{\cdot}382$ Tube F

that is, for the radii the range is from 1 to 47, for the lengths 1 to 307. The whole series of observations given in one of Poiseuille's tables is involved in the determination of η wherever the extrapolation method—formulæ (6*a*) and (6*b*) § 8—has been used. These cases are distinguished in the table by the absence of an asterisk. Those marked with an asterisk give the mean result deduced from the first three members of the series,[2] as I

[1] Poiseuille's method of reduction, vide his memoir, § 142 - 144, p. 526 529, is not only unnecessarily operose, it is erroneous. He applies the radius correction $(1+\zeta)^4$ and the volume correction $(1+\zeta)^3$, but neglects the length correction $(1+\zeta)$: see his note p. 525. He computes the mass instead of the volume of efflux, a procedure which, without compensatory advantage, complicates the reduction.

[2] There are three exceptions to this statement. There is only one experiment each, in the case of tubes M, and M_1. In the case of A_1 the temperature of the first experiment was not 10°, so that the following three were taken.

believe them to have the greatest weight. The corrections to the pressures in these instances have been applied on the assumption that m in formula (3) is 1·12.

There are thirty-six tubes in the series, the flow in the last four is probably unsteady, and therefore the formula of reduction is of doubtful application, as it applies only to the case of steady motion. The general result is

$$\eta_{10} = 0{\cdot}013107$$

and seems to be reliable to four significant figures.

20. *Values of the viscosity and relative fluidities between 0° and 45° C. as deduced from Poiseuille's experiments.—Interpolations.*—Poiseuille's measurements with tubes A, C, D_1 and E, give, to quarter seconds, the times of efflux, for a volume constant for each tube—excepting in so far as it is modified by the expansion of the apparatus—under pressures ranging between 77·3 and 77·6 c.m. of mercury at 10° C.,[1] and their reduction to a common pressure, viz., that last mentioned. These reduced values I have taken as data. The temperatures are about 0·5°, 5°, 10° etc. to 45°, but frequently differ 0·1 or 0·2 from the whole number of degrees. The efflux times have consequently been corrected by interpolation, having regard to second differences, so as to give their value for flow exactly at each fifth degree from 5° to 45°. These again have been corrected for the fall in pressure at the entrance of the tubes, by formula (5) assuming m to be 1·12,[2] the results being expressed to 0·1 second. The efflux times so corrected are as follows:—

[1] I do not remember that this is explicitly stated by Poiseuille, but it may be observed that the values at 10° are those of the earlier series in his memoir, and the method of reduction indicates what I have stated to be the case.

[2] In § 8 it is mentioned that tube A indicated a value for m of 0·4 or 0·5, and that C, D_1 and E gave no satisfactory indication whatever of its value. I have not used this value for A because it depends on a determination by three points only, and in the case of the other three I think the correction mentioned is the most probable.

Corrected times of efflux (seconds).

Temp. *C.*	Tube *A*.	Tube *C*.	Tube D_1.	Tube *E*.
0[1]	*2358·7	*2848·7	†3409·7	*2735·8
0·5	2327·0	2809·2	———	2697·3
5	2014·6	2416·1	2894·1	2314·6
10	1739·7	2087·5	2501·3	2000·7
15	1518·2	1830·2	2191·0	1751·4
20	1337·0	1607·9	1923·0	1542·0
25	1186·7	1427·6	1713·2	1371·8
30	1061·2	1279·7	1531·0	1227·1
35	954·1	1148·5	1374·3	1101·8
40	862·3	1041·3	1243·8	998·4
45	782·2	947·4	1136·9	906·8

It happens, somewhat curiously, that if we take the reciprocals of the efflux times their progression may be represented with considerable exactitude by a curve of the second degree. Simplicity of treatment, and a convenient comparison of the results obtained from each tube, may be simultaneously secured by expressing the fluidity[2] for 0° C. as unity. We therefore divide the efflux times for 0° by those for the other temperatures, the quotients so obtained are entered in the following table.

[1] The values for 0° C. marked * are extrapolated through the values for 0·5°, having regard to third differences, that is to say they are determined by a curve of the third degree whose ordinates for the abscissæ 0·5, 5, 10, and 15 are respectively the corresponding efflux times in the above table. The value for 0° C. marked † is the mean determined by two methods (*a*) and (*b*) the results differing, it happens, only 0·2 second. The method (*a*) was extrapolation through the points determined by the ordinates for 5, 10, 15 and 20. The method (*b*) was:—the sum of the efflux times at 0° for tubes *A*, *C* and *E* divided by the similar sum for the same tubes between the limits 5° to 45° inclusive, was multiplied into the total sum of the times for tube D_1. In regard to the legitimacy of this extrapolation see § 25 hereafter.

[2] The fluidity f has already been defined, § 3, as the reciprocal of the viscosity: the relative fluidity f' will therefore be $1/\eta$ multiplied by some constant.

Relative fluidities of distilled water, 0° to 45° C. as determined from Poiseuille's experiments with glass tubes.

Temp.	Tube *A*.	Tube *C*.	Tube D_1.	Tube *E*.	Mean.	Computed.
0	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
0·5	1·0136	1·0141	———	1·0143	1·0140	1·0170
5	1·1708	1·1791	1·1782	1·1820	1·1775	1·1756
10	1·3558	1·3647	1·3632	1·3674	1·3628	1·3630
15	1·5536	1·5565	1·5562	1·5621	1·5571	1·5621
20	1·7642	1·7716	1·7731	1·7742	1 7708	1·7730
25	1·9876	1·9955	1·9903	1·9943	1·9919	1·9956
30	2·2227	2·2261	2·2271	2·2295	2·2264	2·2300
35	2·4721	2·4803	2·4816	2·4830	2·4793	2·4762
40	2·7354	2·7357	2 7414	2·7402	2·7382	2·7340
45	3·0155	3·0069	2·9991	3·0170	3·0096	3·0036

Taking out the second differences from the column of mean values, we find no definite law of progression, that is to say the third differences are irregular and variable in sign. As the second differences are small, a curve of the second degree will express the results with considerable precision. We therefore put

$$f' = 1 + a\tau + \beta\tau^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (35)$$

f' denoting relative fluidity, τ temperature in degrees centigrade, and a and β the constants to be determined. The mean of the second differences for the 5 degree intervals is 0·01174, so that

$$2\beta \times 5^2 = 0{\cdot}01174 \quad \text{or} \quad \beta = 0{\cdot}000235^1$$

By subtracting from each value of the relative fluidity the corresponding value $\beta\tau^2$ we eliminate the second term from the values of the function, and may thus obtain that of a. This is most conveniently effected by the process represented in the following

[1] More accurately 0·0002348. The change to 0·000235 is not without advantage, for when the first term is subsequently evaluated, the limited number of figures used, more exactly expresses the observed values than if the change had not been made. I venture to think that for practical purposes the type of solution above indicated, together with the consideration of the reciprocal effect of small changes in the coefficients, with a view to securing a simple numerical expression that will represent the observed values, is preferable to the usual method by least squares.

formula

$$a = \frac{\Sigma_0^\tau (f' - 1) - \beta \Sigma_0^\tau \tau^2}{\Sigma_0^\tau \tau} \quad \ldots\ldots\ldots\ldots\ldots\ldots (36)$$

The application of this to the case in hand gives $a = 0{\cdot}03395$. The fluidity is therefore

$$f' = 1 + 0{\cdot}03395\tau + 0{\cdot}000235\tau^2 \quad \ldots\ldots\ldots\ldots\ldots (37)$$

The values in the final column in the above table of fluidities are computed by this formula. With the exception of the values at 0·5° and 40° they lie between the extremes of the observed values.

The absolute values of the viscosity at 10° C. deduced from these experiments are[1]

Tube	A	0·013124	Mean 0·013103
,,	C	0·013026	
,,	D_1	0·013010	
,,	E	0·013252	

This mean corresponds to the value 1·3628 in the relative fluidity: in order to make it agree with the result from the whole of the experiments it must be corrected so as to correspond with the value 1·3630 of the computed curve. Multiplying therefore by the factor 1·3628/1·3630 it becomes 0·013101, and this is the value of η_{10} best representing the whole of these experiments. The mean of the thirty-two determininations at 10° C. in § 9 gave 0·013107. Taking the mean of the two we have for the value of the viscosity at 0° C.

$$\eta_0 = 1{\cdot}3630 \times 0{\cdot}013104 = 0{\cdot}017861$$

and thus for the general absolute value in C.G.S. units as deduced from the whole series of Poiseuille's observations[2] we obtain

[1] The values differ from those given in the first table for the same tubes, inasmuch as these represent one experiment for each tube only, while those represent the mean of a number. The mean of the four from that table is 0·013109.

[2] Poiseuille gives—p. 531 of his memoir—a formula

$$q' = 1836{\cdot}724\,(1 + 0{\cdot}0336793\,\tau + 0{\cdot}0002209936\,\tau^2)\,H\,D^4\,L$$

It is worthy of remark that, accepting his results as they stand, the relatively simple expression

$$q = 1832{\cdot}4\,(1 + {\cdot}0339\,\tau + {\cdot}00022\,\tau^2)\,H D^4\,L$$

more exactly expresses them.

$$\eta_\tau = \frac{0{\cdot}01786}{1 + 0{\cdot}03395\,\tau + 0{\cdot}000235\,\tau^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (38)$$

The expression of the result to any higher order of precision would be misleading. The general exactitude of Poiseuille's experiments leaves little to be desired : it is to be regretted however that the dimensions of the tubes were not obtained to a much higher degree of accuracy, and that the character of the thermometry has not been more explicitly stated. That it was very good is manifest both from an examination of his memoir and from a comparison of the results. For from (37) and (38) we have for the relations of a variation df' in relative fluidity and a variation $d\eta$ of the viscosity to a variation in temperature $d\tau$

$$df' = (0{\cdot}03395 + {\cdot}00047\,\tau)\,d\tau \quad \ldots\ldots\ldots\ldots\ldots\ldots (39)$$

$$-d\eta = (0{\cdot}000606 - 0{\cdot}0000328\,\tau)\,d\tau \quad \ldots\ldots\ldots\ldots\ldots (39a)$$

hence a difference of 0°.1 will account for the difference between the mean and computed values of the fluidity at 0°.5 and at 45°. Moreover 0°.1 will alter the last figure in the coëfficient of viscosity for 0° C. by its whole amount. To determine the viscosity to 1/1000 the measurement of the temperature at 0° C. would have to be to within 0°.03, and at 100° to much less than 0°.01, so that to reach a higher order of precision than Poiseuille's results seem to indicate has been attained, will involve an attentive consideration of each element in a determination, and a complete discussion of the attainable accuracy at every stage of the processes of measurement.

21. *Other measurements of viscosity. Jacobson, 1860.*— Jacobson's measurements of efflux were made with glass and brass tubes, the pressure under which the flow took place being that of the water in the reservoir of supply. His data in addition to the dimensions of the tubes are the 'heads' and velocities the latter being computed from the weight of the efflux in a given time, Hagen's values[1] of the density of water at different temperatures being used and the expansion of the glass and brass being

[1] Abhandl. Akad. Berlin, 1855, Math. Abt. p. 1 – 28.

taken into consideration.[1] Hagen's values are so nearly equal to those of later determinations that corrections were unnecessary. The viscosity was calculated from the formula

$$\eta = \frac{g\, h_0 \rho\, R^2}{8\, L\, U}$$

The variations of the dimensions with temperature have not been taken into account, so that they are uncertain to the extent of the correction $+\zeta$, see section 18 hereinbefore: this however will not materially affect the result, and the data are certainly not of sufficient precision to make the matter worth consideration. The results have been reduced from the temperatures quoted to 0° C. by formula (38). The value of g for Königsberg, where these measurements were made, has been assumed to be 981·44.

Hagenbach, 1860.—Hagenbach reduced his own and other experiments by the application of a formula, which, for C.G.S. units and an absolute value of η, may be written

$$\eta = \frac{\pi R^4 P T}{8 Q L} - k \frac{\rho Q}{\pi L} \cdot \frac{1}{T} \quad \ldots\ldots\ldots\ldots\ldots\ldots (40)$$

This was theoretically deduced and is identical with (4) if $k = m.8$, hence k should be 0·140—see § 8. Hagenbach however used $1/2\frac{1}{3}$; *i.e.* 0·0992, instead. The lengths of his tubes were measured directly, and their radii computed from the contained volumes of mercury.[2] The acceleration of gravity is not given, but I assume it to be about 981·0 centimetres. The value for η at 0° C. given hereafter, is the mean of the results for four tubes of different radii.[3]

Graham, 1861.—Graham measured the efflux times with two tubes—D and E—at frequent intervals of temperature, never greater than 5°, from 0° to 70° C., recording generally to whole seconds, a half second however being occasionally shewn. From the values he gives for Q, L and R, I have reduced his observed times by formula (5), casting the results to 0·1 second. The two tubes do not yield anything like identical values for η, the results

[1] Archiv. fur Anat. u. Phys. 1861, p. 315.

[2] Pogg. Annal. Bd. 109, p. 398. [3] Ibid. p. 400.

for 10° C. being, for tube D ·0112, and for tube E ·0081, instead of ·0131. I suspect that the dimensions are in error, which if true, prejudices the correction of the times—the reduction of T to T_0—a correction of considerable magnitude in these experiments. Despite this, they are valuable as to some extent confirming—contrary to Rosencranz's measurements—the propriety of extrapolating beyond its major limit, the curve expressing the results from 0° to 45° C. Both bulb and tube were immersed in the heating bath, so that no dimensional temperature corrections were required.

Rellstab, 1868.—According to the specific viscosities quoted by Wagner,[1] Rellstab's experiments give for the relative fluidities for each 5° from 0° to 50° the following values, that at 0° being 1000, 1000, 1172, 1361, 1587, 1802, 2053, 2222, 2500, 2688, 2899, 3205. These agree well with Poiseuille's values, but in the absence of the experimental data I have been unable to apply the revised correction for fall in pressure at the tube entrance.

Sprung, 1876.—Sprung's observations have been reduced on the assumption that the dimensions of the tube and bulb are given for the same temperature, and that the 'head' H represents pressure in grammes per square centimetre. Sprung used Hagenbach's correction to the pressure.[2] The reservoir and capillary being both immersed during the experiments, dimensional corrections were not required.[3]

Rosencranz, 1877.—In Rosencranz's apparatus the reservoir of supply, a bulb by means of which the volume of efflux was measured, was *not* raised to the temperature of the liquid in the capillary. This complicates the reduction. Let Q denote the volume of the reservoir at the temperature for which the dimensions of the tube are given, and ρ the density of water at that temperature, then the effluent volume Q' at τ degrees above this temperature, the density being then ρ', will be

[1] Wied., Annal. Bd. 18, p. 263.

[2] Pogg. Annal. Bd. 159, p. 6. [3] Ibid, p. 5, 6.

$$Q' = Q\frac{\rho}{\rho'} = \frac{\pi}{8} \cdot \frac{P_0 R^4}{L\eta}(1+\tau\xi)\,T.$$

ξ being the coëfficient of cubic dilatation. Thus, for measurements of dimensions at all ordinary temperatures we have with ample precision

$$\eta = \frac{\pi P R^4}{8 L Q}\left\{ T(1+\tau\xi+\rho'-\rho) - \frac{1{\cdot}12\,Q^2}{\pi^2 P R^4} \cdot \frac{1}{T} \right\} \ldots\ldots\ldots(41)$$

The correction represented by the term $\tau\xi$ is rejected by Meyer, in his reduction of Rosencranz's observations, as negligible[1]: its maximum value is however about 1/500, and it affects the computed values of η from 4 to 7 units in the last place of figures, viz. the fourth.

The pressure registered by the manometer was throughout 59·3 centimetres of mercury at 18° C. Meyer takes this to be of 13·415 density and equivalent to a column of water of 795·6 c.m. height: to this has to be added 9·0 c.m., owing to the disposition of the apparatus, thus making a total of 804·6 c.m.[2] But this value for the density is, I suspect, an error, and I have therefore recomputed the pressure, obtaining the result 812·59 grammes per square centimetre. The bulb measuring the influx contained 111·03 grammes of water, which I take to represent a volume of 111·178 cubic centimetres at 18° C., the laboratory temperature.[3] The capacities of the tubes were found by filling with mercury and the mean radius so determined.[4] The reduced results can be expressed in the form[5]

$$\eta_\tau = \frac{\eta_0}{1+\alpha\tau}$$

but they do not appear to be satisfactory either intrinsically, when compared with Graham's observed values, or with those obtained by extrapolating the curve given by Poiseuille's measurements.

[1] Wied. Annal. Bd. 2, p. 399—"doch kann diese Correction ihres geringen Betrages wegen unterbleiben."

[2] Ibid. p. 397. [3] Ibid. p. 397.

[4] Ibid. See also Pogg. Annal. Bd. 148, p. 36, 1873. Tube III.

[5] η_0 was ·01854 and α ·04635.

The values given by me are obtained by interpolation: in the original work the temperature-intervals are irregular.

Přibram and Handl, 1878.—I have not reduced the observations of these investigators. The times of efflux are short, about 84 to 199 seconds, the temperatures are at irregular intervals from 13·9° to 56·4°.[1]

Grotrian, 1879.—The lengths of the two tubes used by Grotrian were measured by a cathetometer to ·005 c.m., at what temperature is not stated, and their sections were derived from measurements of their capacity.[2] The content of the measuring bulb was 40·3465 grammes at 16°.57 C.: its capacity was evalued by Grotrian for 28° the middle temperature in his efflux experiments. Assuming however that the other measurements were also made at about 16°.57 I have, as is requisite, found the capacity for that temperature, the result being 40·390 c.cm. The apparatus was wholly submerged in the heating bath.

Slotte, 1881.—With the one tube Slotte measured the efflux four times at each of the temperatures 10, 20, 30 and 40 degrees C., these being registered by a corrected (justirtes) thermometer, graduated to tenth degrees.[3] No information is given in the account of his experiments as to the conditions under which the dimensions of his apparatus was ascertained. The apparatus and method of using it was similar to Sprung's, hence dimensional temperature corrections are not needed. Slotte proposed a formula by which the viscosity might be put in the form[4]

$$\eta_\tau = \frac{A}{B+\tau} - C.$$

He used Hagenbach's correction.[5]

---

[1] Sitzber. Akad. Wien., Bd. 78, Abt. 2, p. 113 - 164.

[2] Pogg. Annal. Bd. 160, p. 264.

[3] Wied. Annal. Bd. 14, p. 13.

[4] According to the Chemical News, Vol. 69, No. 1790, p. 123.—Thorpe and Rodgers in the Bakerian Lecture of the Royal Society, give reasons for preferring Slotte's formula $\eta = c_1'(1+b\tau)^n$. I have not seen their paper.

[5] *Loc. cit.*, p. 17.

Wagner, 1883.—Wagner's measurements of efflux were all with one tube, four experiments being made at every 5° from 15° to 50°. His apparatus was similar to Wiedemann's[1] and Sprung's. I assume, as I did in reducing Slotte's work, that Wagner's dimensions are evaluated for the one temperature, though definite information on the point is not given. He used Hagenbach's correction. In regard to the pressures, I conclude that *H* indicates grammes per square centimetre.

Reynolds, 1883.—Two of the tubes used by Reynolds were leaden pipes whose radii were 0·3075 and 0·635 cm. In these the fall in pressure between two points 152·4 cm. apart was measured by the vertical height of columns of water sustained at those points, *i.e.* by the 'hydraulic gradient' of the pipe. Though not exactly equivalent to the fall per unit of length expressed in grammes per square centimetre, the agreement is sufficiently approximate in relation to the order of precision in the data, to render the application of a correction unnecessary. In my reductions I have assumed the acceleration of gravity to be 981· cm. The temperatures do not appear to have been measured with great precision so that the deduced value of η must be considered as merely approximate. It is worthy of remark however that it does not differ more than 1/27 from the value obtained from a tube (*M*, Poiseuille's) the area of whose section was only about 1/800000 of the larger of these tubes.

Röntgen, 1884.—The object of Röntgen's experiments was to ascertain the effect of pressure on the viscosity. He measured the times of the efflux under pressures varying from 19 to 29 atmospheres, as well as those under pressures of 1 atmosphere, the temperatures being approximately 6° and 11° C. There is not sufficient information to determine the absolute or relative fluidities at these temperatures, nevertheless the effect of variations of pressure can be fairly well ascertained. The change in the fluidity with such variations is so slight that the correction for

[1] Pogg. Annal. Bd. 99, p. 221, 1856.

loss at the entrance to the tube is sensibly the same for efflux at constant temperatures under any pressure,[1] for the times of efflux are very nearly equal. The results have been reduced to their values at 6° and 11° C. by formula (37), and the higher pressures to the value for 24 atmospheres.

König, 1885.—Using two tubes of nearly equal sectional area, König made five efflux experiments between the temperatures 15·5° and 18·1° C., correcting by Hagenbach's formula. In my reduction I have assumed g to be 980·95: its value was not mentioned in König's account of his work.

Couette, 1890.—In his interesting 'Études sur le frottement des liquides,' Couette gives a method of observation by which the corrections for fall in pressure at the entrances of tubes and for their end conditions—see (12a) and (13)—are eliminated. By means of selected capillary tubes of equal radii, but of very different lengths, he connects three reservoirs, through which a flow from a still larger reservoir is established under pressure, the efflux through both tubes finally becoming equal. The pressures in the three reservoirs are then measured by a manometer of three branches. Putting $\gamma = m\rho q^2/(\pi^2 R^4)$, l having the same signification as in § 9, P_1 denoting the fall in pressure between the reservoirs connected by L_1, and P_2 the corresponding fall between the reservoirs connected by L_2, we have

$$q = \frac{\pi R_1^4}{8\eta} \cdot \frac{P_1 - \gamma_1}{L_1 - l_1} = \frac{\pi R_2^4}{8\eta} \frac{P_2 - \gamma_2}{L_2 - l_2}$$

hence if, as there is reason to believe, $\gamma_1 = \gamma_2$ and $l_1 = l_2$, and if also it were possible to employ two tubes of equal radius R, we should have

$$q = \frac{\pi R^4}{8\eta} \cdot \frac{P_1 - P_2}{L_1 - L_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(42)$$

Couette's formula.[2] But more rigorously it may be assumed that this is not possible; and therefore we are involved in considering

[1] The difference in the correction will probably always be less than the unavoidable errors in the recorded times of efflux.

[2] Annales de Chimie et de Physique, 6 sér. t. 21, p. 468–472.

the application of Couette's method when an inequality in the radii is known to exist. Let, as in § 12 and § 14, R_1 denote the 'mean radius of efflux' of tube 1, etc.—*i.e.* the radius of a right circular cylinder of equal discharge—then putting, similarly to our previous notation,

$$R^4 = \tfrac{1}{2}(R_1^4 + R_2^4) \text{ and } e = \frac{R_2^4 - R_1^4}{R_2^4 + R_1^4}$$

we obtain

$$\eta = \frac{\pi R^4}{8q} \cdot \frac{P_1 - P_2 - (P_1 + P_2)e}{L_1 - L_2} + \frac{2e\gamma}{\ldots\ldots\ldots\ldots\ldots\ldots(43)}$$

that is, the correction l is eliminated, but not γ. The term $2e\gamma$ is probably however always negligible, but not so $(P_1 + P_2)e$. This result is important as shewing that when the radii are unequal the deduced value of the viscosity depends not merely upon the difference of pressures in the reservoirs, but also upon their absolute amounts.

I have not from Couette's data reduced afresh the values of the viscosity, but accepting them for the particular temperatures of his own observation, reëxpressed them for other temperatures by formula (37).

Cohen, 1893.—Cohen's extended series of experiments, by the efflux method, to ascertain the effect of pressure on the viscosity of liquids, cannot be used to obtain absolute measures, as only the approximate dimensions of his tube,[1] and of the fall in pressure therein,[2] are given. In his own reduction his times are uncorrected and although this does not sensibly affect the results, for the reasons pointed out in referring to Röntgen's experiments, the series of experiments seemed well worth rigorous reduction. For the purpose of the reduction of the times, the volume of efflux — which was not given—may be computed from the known value of the viscosity, so that instead of finding T_0 by (5) we must use[3]

[1] Wied. Annal Bd. 45, p. 666. [2] Ibid. p. 669.

[3] This formula is of course derived by substituting for Q^2 in (5) its approximate equivalent in terms of the other quantities, supposed known only with sufficient accuracy for the purpose of the correction.

$$T_0 = T - \frac{m\rho P T R^4}{64 L^2 \eta_0^2} (1 + \alpha\tau + \beta\tau^2)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (44)$$

which is quite satisfactory since the corrective term is small.

22. *The value of* η_0.—The value of the viscosity of water a 0°C. —viz. $\eta_0 = 0{\cdot}01786$ formula (38) corresponding to $\eta_{10} = 0{\cdot}013103$, and deduced by a rigorous reduction of Poiseuille's efflux measurements—is among the smallest of those obtained from the experiments of different observers, see the second table of § 6. This is probably attributable to the fact that, of all tubes of equal sectional area, the right circular cylinder gives the greatest discharge, whence it follows that where the radii have been computed from the measurements of capacity on an erroneous assumption of that form, the departures therefrom must necessarily, as shewn, in § 11 to § 16, give values greater than the true one. Poiseuille's tubes seem to have been the only ones whose sections were measured directly, and at several points along the axes, consequently it is to be expected that the value of η, deduced from his experimental data by the application of corrections for the departure from the circular cylindrical form, will be approximately the minimum. Its smallness, as compared with the results of other observers whose data do not include material for these corrections, in no way diminishes our confidence in it as a reliable value, and one really representing, in numerical form, a physical property of water; whereas in regard to the larger values one very properly suspects that had such data been to hand, the appropriate corrections, then possible, would have made the results more accordant, since they are always negative in sign. At the same time we do not prefer the smallest value because errors of measurement, either of dimensions, pressures or times, are as likely to be negative as positive.

For purposes of comparison the following values of the viscosity at 0° C. have been recomputed from the original data, using Boussinesq's value for m in (5), the reduction to 0° being made by multiplying by the relative fluidity f—formula (37). The temperatures quoted are those of the experiments.

Viscosity of Distilled Water at 0° C., computed from the efflux measurements of various investigators.

Observer.	Date.	Expts.	Tube.	Temp.	η_0.
Poiseuille	1846	series	glass	0° – 45°	0·01786
Jacobson	1860	4	,,	16°.7	1808
,,	,,	4	,,	15·2	1800
,,	,,	3	,,	11·3	1867
,,	,,	2	,,	12·2	1770
,,	,,	3	brass	13·4	1755
,,	,,	3	,,	15·7	1809
,,	,,	1	,,	16·7	1806
,,	,,	5	,,	15·2	1786
,,	,,	4	,,	12·8	1778
,,	,,	7	,,	16·5	1794
,,	,,	5	,,	16·4	1795
Hagenbach	1860	4	,,	17·4	1844
Sprung	1876	21	,,	0° – 15°	1773
Rosencranz	1877	2	,,	42°.5	1797
Grotrian	1879	2	,,	14°.9	1798
Slotte	1881	4	,,	10°	1814
Wagner	1883	4	,,	15°	1797
Reynolds	,,	22	lead	5° – 12°	1834
König	1885	5	glass	16°.8	1771
Couette	1890	2	copper	16·4	1819
,,	,,	3	white metal	18·5	1817
,,	,,	3	paraffin	12·6	1853

23. *The relative fluidities of distilled water at ordinary pressures for temperature 0° to 50° C.*—Small errors in the dimensions of tubes prejudice but slightly the reduction of the relative fluidities, inasmuch as they affect only the correction for the fall of pressure at the entrance of the tube. That the dimensions given are, with the exception of Graham's, sensibly correct, is evident from the fact that the absolute values of the viscosity derived from them are nearly identical. The results however do not exhibit as perfect an agreement as one might perhaps have expected. The value for 0° C. has been taken as 1000 instead of unity.

Relative Fluidities of Distilled Water 0° to 50° C., computed from the efflux measurements of various investigators.

Temp.	P$_4$ 1846.	Gd 1861.	Ge 1861.	S$_4$ 1876.	Gi 1879.	Gii 1879.	Sl$_4$ 1881.	W$_4$ 1888.
0° C.	1000	1000	1000	1000	...	...	...	1000*
5	1177	1188$_3$	1185$_2$	1176	...	...	...	...
10	1363	1364	1373	1366	...	...	1363	...
15	1557	1582$_3$	1575	1566	1557$_2$	1563$_2$	...	1568
20	1771	1802	1791	1775	1765$_2$	...	1767	1795
25	1992	2053	1990	1983	2001$_1$	1996$_2$	...	2002
30	2226	2272	2207	2218	2227$_3$	...	2213	2263
35	2479	2535	2452	2457	2511$_2$	2494$_1$	...	2509
40	2738	2781	2736	2705	2724$_2$	2728$_1$	2719	2763
45	3010	3041	2985	2957	...	...	...	2944
50	3285*	3337	3279	3218	...	...	...	3213

NOTE.—* Denotes that the value is extrapolated. The small numbers as $_4$ etc., denote the number of experiments on which the value is based. P = Poiseuille: Gd = Graham, tube *D*: Ge = Graham, tube *E*: S = Sprung: Gi = Grotrian, tube 1: Gii = Grotrian, tube 2: Sl = Slotte: W = Wagner.

24. *The relative fluidities of distilled water for temperatures above 50° C.*—So far as I am aware, only two observers have given measurements from which the fluidity for temperatures above 50 C. can be ascertained, viz. Graham and Rosencranz. Meyer, who reduced Rosencranz's data, concludes that above 50° the fluidity is related to the temperature by a linear function, viz.

$$f_\tau = f_0 \ (1 + \acute{a}\,\tau)$$

but Graham's results do not tend to confirm this view. In the table hereunder, the design of which is to illustrate this point, the first column P* contains the values of the fluidity obtained by extrapolation from the results of Poiseuille's experiments, formula (37): the second and third columns those of Graham with tubes *D* and *E*, his measurements being made at the temperatures quoted: the final column R*, contains the values roughly interpolated from Rosencranz's measurements.[1] The fluidity at 0 C. is taken as 100.

[1] The temperature intervals were irregular and as the results could not be closely represented by a curve without inflexions, only rough interpolations were possible.

Relative Fluidities of Distilled Water, 50° to 90° C.

Temp.	P*	Gd	Ge	R*
50° C.	328	334	328	327
55	358	360	349	354
60	388	387	380	372
65	420	415	418	398
70	453	448	444	421
75	487	...	...	443
80	522	...	...	462
90	596	..	...	546

The results indicate that the form of the curve best representing the relative fluidity, is not well determined for temperatures above 50°, and that further experiments are required. Probably it will be found that α in formula (37) must be slightly increased and β diminished.

25. *Relative fluidity of distilled water near the temperature of maximum density.*—The curve of relative fluidity gives some indication of an inflexion at about the temperature of maximum density 4° C. as will be seen from the following results for temperatures 0° to 10° C.

Temp.	Pa	Pc	Pe	Gd	Ge	S	Mean.
0°	1000	1000	1000	1000	1000	1000	1000
0·5	...	1014	1014	...	...	...	1014
0·6	1022	...	...	...	...	...	1022
1	...	...	...	1061	1039	...	1050
2	...	...	....	1091	1076	..	1084
3	...	...	...	1123	1115	...	1119
4	...	...	...	1157	...	...	1157
5	1171	1179	1182	1187	1180	1176	1179
7	...	...	...	1258	1265	...	1261
10	1356	1365	1367	1364	1373	1366	1365

NOTE.—Pa, Pe and Pe, are results from Poiseuille's tubes *A*, *C* and *E*; Gd and Ge from Graham's tubes *D* and *E*; and S from Sprung's.

Subtracting the values obtained by assuming that the fluidities from 0° to 10° C. are given by the expression $1000 + 36{\cdot}5\tau$, from

those in the last column—the means—we obtain

Temp.	0°	0·5	0·6	1	2	3	4	5	7	10
Diff.	0	− 4	0	+ 13	+ 11	+ 10	+ 11	− 3	+ 6	0

that is the differences are generally positive and are sensible. The curve best representing the mean values must therefore take the form

$$f'_\tau = 1000\,(1 + \acute{\alpha}\tau - \beta'\tau^2)$$

between these limits, and since from 5° to 45° C. the second coëfficient β, was positive—formula (37)—there is an inflexion in the curve. To determine the point of inflexion, extremely accurate measurements of the viscosity would be necessary. The change in the form of the curve from 0° to 5° somewhat vitiates the extrapolation—though it be for only a half degree—by which the efflux time for 0° C. was obtained in § 20.

26. *The variation of the fluidity with pressure.*—The effect of pressure is to increase the fluidity or to diminish the viscosity, at least for temperatures under 30° C.[1] This is best shewn by Cohen's method of expressing the value at each temperature for one atmosphere as unity: in this way the results become independent of the relative fluidities for the different temperatures.[2] The values for a pressure of 24 atmospheres are from Röntgen's, and those for higher pressures from Cohen's experiments.[3]

Effect of Pressure on Fluidity at 15° C., according to Cohen's Experiments.

Atmos. =	100	200	300	400	500	600	700	900
I.	+ 0072	0127	0150	0219	0208	——	0230	0270
II.	+ ·0051	0126	0161	0223	0258	——	0245	——
III.	+ ·0047	——	0152	——	——	0239	——	0284
Mean	+ ·0057	0127	0154	0221	0233	0239	0237	0277

NOTE.—The fluidity under a pressure of one atmosphere is unity: that at any other pressure is 1 + the decimal in the table.

[1] Under 40° C. according to Cohen—Wied. Annal. Bd. 45, p. 684.

[2] The relative fluidity cannot be accurately determined from the data.

[3] The figures are not always identical with Cohen's: this however is not due to the application of the small correction to the time, but to errors in computation.

The only anomalous result in the above table is that for 700 atmospheres; the value is probably too small.

Effect of Pressure on the Fluidity at various Temperatures, according to Röntgen's and Cohen's experiments.

Temp.	Pressure in Atmospheres.								
C.	24	100	200	300	400	500	600	700	900
1°	——	0215	——	0327	——	——	0670	——	——
6°	+·0285	——	——	——	——	——	——	——	——
11°	+·0197	——	——	——	——	——	——	——	——
15°	——	0057	0127	0154	0221	0233	0239	0237	0277
23°	——	0047	——	0077	——	——	0100	——	——

NOTE.—The fluidity under a pressure of one atmosphere is unity for each temperature: that at any other pressure is 1 + the decimal in the table.

The available information is insufficient for the deduction of a general formula expressing the fluidity as a function of temperature and pressure, for as pointed out by Cohen it is yet undetermined whether at higher temperatures the viscosity instead of being diminished by pressure, is increased.[1]

27. *The value of the viscosity by the rotating cylinder method.*— The values of the viscosity of water as found by other methods have differed greatly from that obtained by the efflux method. In a recent investigation by Brodmann, this difficulty though not completely is at any rate partially resolved. From experiments of type (*e*) § 1, using three cylinders of different sizes,[2] he obtains the following values (i) and (ii) for the viscosity at 15° C. respectively from the smallest and middle, and smallest and greatest cylinders. Poiseuille's value (iii.) as deduced herein is indicated also for comparison

(i.) $\eta_{15} = 0{\cdot}01265 \pm 0{\cdot}00049$
(ii.) $\eta_{15} = 0{\cdot}01228 \pm 0{\cdot}00011$
(iii.) $\eta_{15} = 0{\cdot}01143$

[1] *Loc. cit.* p. 684.
[2] Wied. Annal. Bd. 45, p. 178, see also p. 179.

IV.—Indications for a further Determination.

28. *Apparatus.*—Some observations in regard to the general disposition and dimensions of apparatus for a further determination by the efflux method of the viscosity constant, may not be inappropriate in concluding this examination of the subject. Fig. 4 indicates the general arrangement of the essential parts best adapted to the purposes of accurate measurement[1]—it is essentially Poiseuille's. The pipe P is connected with the source of pressure—compressed air contained in a large reservoir in Poiseuille's experiments,—continuous with it is the pipe M communicating with the manometer. When the cock-valves K and L are turned the pressure compels the contained liquid in the reservoir bulb V, to flow through the tube JA, the capillary AB, and the efflux tube BE, whence it emerges into the water in the heating bath W, carefully maintained at constant temperature and height, the temperature—that at which the viscosity is to be determined—being measured by the thermometers T, T. The tubes JA and BE ought to be of the same diameter, and the terminals A and B of the capillaries may if possible be inserted well within them. The small bulb U is intended to hold sufficient liquid to permit the flow to be thoroughly established under the general conditions of an experiment, before the measurement actually commences, and, with the rest of the apparatus mentioned, is wholly submerged in the heating bath. R is a microscope—or short-focus telescope—for noting the instant at which the base of the concave surface of the fluid crosses the line I on the tube. This microscope after the observation has been made should be lowered exactly the distance IJ, so as to observe the instant of passage across the line at J, the interval between the two being the time of efflux (T). A chronographic record of these instants is the more satisfactory.

The valves K and L should be closed immediately on the termination of an experiment, so that impurities may not enter the

[1] The figure is not even approximately to scale; it is essentially only diagrammatic.

capillary. It is almost unnecessary to say that the water used in the flow should be most carefully freed from organic particles. The pressure and temperature, which should be sensibly constant, ought to be read at intervals during the efflux, and also the height of the surface of the water in the heating vessel above I and J at its commencement and termination, the latter in order to afford material for correcting the pressures registered in the manometer. The terminals A B of the capillary must be set exactly horizontal, say by means of a cathetometer, and the parts K to A and B to E firmly connected with the heating vessel, in such a way however as to permit of their adjustment—not shewn in Fig. 4.

The tube $B\,E$ serves to ensure constancy in the terminal condition of the efflux. It should be mentioned that the method of allowing the effluent to drop from the tube terminal is unsatisfactory.[1]

The corrections to the immediate data of an experiment are :—

(a) Corrections of the thermometers.

(b) Reduction of the pressure registered in the manometer on account of the pressure conditions in the apparatus.

In regard to (a) if we propose a precision of a higher order than 1 in a 1000, we must read to ·001 degree C., and therefore must follow the methods of rigorous thermometry. With respect to (b):—if the bulb V be symmetrical in form, then since the general height of the water in the bath is not sensibly altered by the addition thereto by the efflux, we have—putting h for the height of the water surface above I at the beginning of the experiments and h' for the similar height above J at the end—for the mean pressure

$$P = g\,(\mu H - \rho\,\frac{h+h'}{2}) \quad \ldots\ldots\ldots\ldots\ldots\ldots(45)$$

H being the mean value of the sustained column in the manometer,

[1] See Mém. des Sav. étrang. t. 9, § 10, p. 440. Also Hagen, Abhandl. Akad. Wiss. Berlin, 1854, p. 17 etc.: and Meyer, Wied. Annal., Bd. 2, p. 398.

μ the density of the mercury therein, and ρ that of the water, both at their own temperatures at the time of the measurement.[1]

As already pointed out no correction for change of dimensions in bulb or capillary is needed, but these must be given for a common temperature.

The only further corrections then are :—(c) the correction for fall of pressure at the entrance of the capillary, (d) that for fall in pressure producing the flow in the tube JA and BE, and (e) a possible correction to the length of the tube to equate the terminal resistances—§ 9. Of these (c) and (e) have been already fully discussed : (d) only requires attention. Let R and S denote respectively the radii of the capillary and supply tube, and L and Z their lengths, then the fall in pressure p_s in the tubes $JA+BE$ is

$$p_s = \left(\frac{R}{S}\right)^4 \frac{Z}{L} P_0 \ldots\ldots\ldots\ldots\ldots\ldots(46)$$

This must be so small as to be practically negligible.

29. *Dimensions of apparatus.*—The general principle which determines the relation of the several parts of the apparatus is that the resultant precision should be uniform throughout. The following measurements are merely suggestions as to a suitable size for the essential parts : they serve also the purpose of illustrating the application of the above principle. We shall assume for g the value 980·6 c.m. and for μ 13·5958.

Pressure in manometer $H = 100$ cm. mercury: hence $P = 133200$
Radius of capillary $R = 0{\cdot}01$ cm. Length $L = 50$ cm.
Bulb V in Fig. 4 $Q = 50$ c.cm. Rad. bulb 2·28 cm. about
Supply tube not less than $S = 0{\cdot}1$ cm. Total length $Z = 25$ cm. say

In apparatus of these dimensions the fall in pressure in the supply tube $JA + BE = Z$ will be not more than

$$(\tfrac{1}{10})^4 \times \frac{25}{50} \times 133320 = 67 \text{ or } 1/20000 \text{ th.}$$

formula (46). The rate of flow even for 0° C. would be sufficiently

[1] The variation in the loss of pressure at the entrance to the tube is so small that it may be computed from this mean pressure, without error.

rapid to allow of a record to a small fraction of a second,[1] whereas the total time of efflux is more than 8000 seconds or over two hours. The correction of the efflux time for fall in pressure at the entrance of the tube is about 24900 sec. T, or about 1 2700th for 0° C.—formula (5)—or the correction to be applied to the deduced viscosity about 0·0445 T—formula (40)—so that a small uncertainty as to its proper magnitude will not greatly vitiate the result.

The volume of the bulb F would be ascertained readily and with sufficient accuracy from its capacity, by using quicksilver. The measurement on the accuracy of which the result mainly depends is the capillary radius, 0·1 millimetre. To obtain its value to considerably under 1/10000 th part[2] is not an easy task. The whole volume of the tube represents only 0·214 gramme of mercury, so that on this element of the work—*i.e.* the evaluation of the 'mean radius of efflux' of the tube—by far the greatest expenditure of effort to attain precision will be required. This applies when the absolute determination of the viscosity is required.

The following series of experiments seems to me to meet the requirements of a thorough determination :

Temp. every 5°, 10° – 95° C.;	$H = 100$;	$L = 50$
every 0°.5, 0° – 10° C.	$H = 50$;	$L = 50$
and	$H = 100$;	$L = 25$
also at 4° C.	$H = 100$, 50, and 25 ;	$L = 50$
and	$H = 100$	$L = 50$, 25 and 12·5

Such a series ought, with care as to dimensions, careful thermometry and generally good manipulation, to satisfactorily settle

[1] The supply tube may be of any convenient size, but it is always necessary that at the points I and J the velocity shall be sensible when viewed by the microscope R. If constricted great care should be taken that the constricted diameters are equal so that the concavity of the water may be the same at each point.

[2] Corresponding to a precision of over 1/2500 th.

the value of the constant, and determine with precision the form of its variation with temperature.[1]

---

1 I regret that the pressure of other duties prevents me from undertaking this task, and of availing myself of the very kind offer of the Professor of Physics—Richard Threlfall, M.A.—to place the resources of his laboratory at the University of Sydney at my disposal for this purpose. I may be permitted also to express my thanks to that gentleman for some critical observations on the first two parts of this paper.

On the PHYSIOLOGICAL ACTION of the VENOM of the AUSTRALIAN BLACK SNAKE (*Pseudechis porphyriacus*).

By C. J. Martin, B.Sc., M.B. *Lond.*
(From the Physiological Laboratory of the University of Sydney.)

[*Read before the Royal Society of N. S. Wales, July 3, 1895.*]

I.—Introduction.

The mechanisms associated with the life of higher animals are so complicated and at the same time so interdependent, that it is always a matter of extreme difficulty to ascertain, with anything approaching to precision, which part or parts of the intricate machinery are influenced by the introduction of a disturbing element from without. When such disturbing element in the form of a poison is introduced, the observer can see without difficulty the end result, but the unravelling of the process requires the closest observation and the assistance of every method of analysis known to the physiologist. Even then, how far we are from a complete understanding of the process! Our conception of the method of operation of any particular poison is necessarily limited by the present condition of physiological science, and the most an observer working in any particular corner of this great field can do, is to attempt to bring the level of knowledge of the particular phenomena he is studying up to that of the science generally, and perhaps to elucidate in some small way by obser-

vations on particular cases, the larger problems with which physiology is concerned.

The research, the results of which form the subject of this paper, was conducted entirely by experiments upon the lower animals. Conclusions as to exact physiological action drawn from the observation of cases of snake-bite in the human subject, while of great importance, are necessarily unsatisfactory owing to ignorance and want of control of so many factors concerned. When confronted with a case of snake-bite our principal duty is to treat the patient, and although we may carefully observe clinical symptoms, the employment of those more accurate analytical methods which can be performed on the lower animals, is impossible. Another disadvantage is that no single observer can hope to witness a sufficient number of cases of snake-bite, but must base his conclusions to a large extent upon the observations of others.

On the other hand, it is true, that it is a mere inference that results obtained upon lower animals can be applied to man. Nevertheless when one considers the identity of mechanism which underlies what differences do exist, together with the fact that the higher mammalia react to snake poisons with striking similarity to mankind, the inference would not appear to be an unfair one.

II.—Methods of Introduction of the Venom.

Venom may enter the body by a variety of channels. The time of onset and the train of symptoms vary according to the rapidity of its absorption. Usually in cases of snake-bite the poison is deposited in the subcutaneous tissues, whence it reaches the general circulation principally by absorption through the blood-vessels. In some experiments I made with the object of determining the relative absorption through the blood-vessels directly, and through the lymphatics, I found that the symptoms of poisoning were not appreciably delayed by previous ligature of the thoracic duct. The poison was in each case injected into the subcutaneous tissue of the thigh. The venom is more rapidly absorbed when

introduced into a serous sac, such as the pleural or peritoneal cavity, and its effects are most rapidly manifested when it is introduced directly into a vein. Absorption of venom takes place from such mucous surfaces as the corneal conjunctiva.

Whether venoms can be absorbed by the mucous membrane of the alimentary canal has been much discussed. Weir Mitchell[1] came to the conclusion from numerous experiments on pigeons that Crotalus-venom was not absorbed from the crop. If however abrasions were artificially produced, symptoms of poisoning resulting in death occurred. Fayrer[2] and Richards,[3] on the other hand, found cobra-venom was absorbed to some extent, from the alimentary canal. Mitchell has confirmed these statements of Fayrer and Richards, but found that absorption through this channel was very slow.

I have repeated Mitchell's experiments, to determine whether *Pseudechis* venom was absorbed from the alimentary canal. In my own experiments I used rats instead of pigeons.

Two white rats were fed daily for one week on bread and milk, containing one hundred times a fatal dose of venom, supposing it to have been administered subcutaneously. At the end of the week both rats were in excellent health. Within half an hour after partaking of the last poisoned meal, the mucous membrane of the stomach of one of them was artificially abraded. This rat died in two hours thirty-five minutes afterwards with the usual symptoms of snake poisoning. Similar abrasions produced in a rat on unpoisoned diet were followed by no untoward symptoms. The whole of the fæces of these rats were collected and examined for venom. The filtrate was treated with a large excess (ten volumes) of absolute alcohol, and the precipitate which formed allowed to remain under the alcohol fourteen days. The precipitate was then extracted with

---

1 Researches upon the venoms of poisonous serpents."—Smithsonian Contributions to Knowledge, Vol. XXVI.

2 "Thanatophidia of India."—Churchill, London, 1872.

3 "On the nature of snake poison and its action on the blood."

dilute saline solution. The extract which contained some proteid was quite harmless when injected under the skin of frogs and mice.

If any quantity of the venom had been absorbed by the rats from the amount contained in their meals, they must have shown symptoms, and had the fœces contained any of the venom, symptoms of poisoning would have occured in the small animals injected with the last saline extract, for *Pseudechis* venom is unaltered by sojourn under absolute alcohol. Accordingly, one must conclude that the venom was either not absorbed, or if so only to a small extent, and that the greater part was destroyed in the alimentary canal. The venom is destroyed by artificial pancreatic digestion, and that the same happens in the intestine is extremely probable. The toxic properties of this venom are however not destroyed by artificial gastric digestion, and the results of the experiments on the rats show that the poison exists in the stomach in an active condition. The walls of this organ are lined by a continuous layer of living epithelium cells, and cannot be reckoned with as if they were composed of a dead membrane. Indeed there is abundant evidence to show that in the process of absorption from the alimentary canal physical processes (osmosis, diffusion) are overborne by physiological ones,[1] and that the lining cells exercise a selective control over the process of absorption.[2] The toxic proteids of some of the infectious diseases also, are not absorbed from the alimentary canal, for Tizzoni has shown that the most virulent tetanus toxines produce no ill effects when administered by the mouth. Absorption does however probably occur to a small extent, for the remaining white rat, was after the lapse of a week, injected with one and a half times a lethal dose of venom, from the effects of which it recovered after suffering slight malaise.

[1] Leubuscher, Jenaische Zeitschrift, Bd. xviii., 1885; Röhmann, Pflüger's Archiv., Bd. xli. 1887; Heidenhain, ibid., Bd. xliii., 1888; Bd. lvi., 1894.

[2] Tappeiner, Wien. Sitzungsberichte, Bd. lxxvii., Abtheil. iii., 1878; Edkins, Journ. of Physiol., xiii., 1892; v. Mehring, Verhand. d. xii., Congress f. innere Med. z. Wiesbaden, 1893, p. 471.

This resistance may be accounted for by the immunising effect of the absorption of small quantities of venom from its food during the previous week.

Before considering the experimental results obtained upon animals it is necessary to emphasise the fact that the effects of a venom introduced directly into the circulation may be very different to those which follow subcutaneous inoculation. These differences although no doubt essentially dependent upon the varying rapidity with which the poison reaches the blood, are from the peculiar nature of its action on this fluid, of such a kind as to be misleading. On reference to the portion of this paper devoted to the consideration of the action of snake-poison on blood-plasma it will be seen that the venom of *Pseudechis* if introduced with sufficient rapidity into the circulation, occasions extensive intra-vascular clotting. The venom may reach the blood with a rapidity adequate to cause thrombosis, either when directly introduced into the circulation or if subcutaneously injected in sufficient quantity in a situation favourable for absorption.

When one sees an animal, within a few seconds or minutes after the introduction of the poison, seized with convulsions over which artificial respiration has no influence, and closely followed by death or a condition of profound depression, one might naturally imagine that the poison had exerted its influence directly upon the nervous system. In the case of such symptoms following the introduction of the venom of the species of Australian snakes I have hitherto examined, such a supposition would be erroneous, for by opening the animal just prior to death, the venous system would be found to be the seat of more or less extensive thrombosis.

Intravascular clotting is also in my opinion the explanation of the convulsions which have been observed by Wall[1] and others, to rapidly follow the introduction of viperine venom into mammals, and which form such a marked feature in the experiments with

[1] Wall, Indian snake poisons, their nature and effects.—Allen & Co., London, 1883; Proc. Roy. Soc., Lond., Vol. XXXII., 1881.

the venoms of this class of snakes. Such early convulsions must not be confused with those due to failure of the respiration, which immediately precede death from cobra poisoning.

With subcutaneous injection, the venom does not, as a rule, reach the blood with sufficient rapidity to occasion any extensive thrombosis, but under these circumstances the blood is found to have its coagulability greatly diminished or lost. These opposite conditions are in reality two phases of the same operation.

As thrombosis in different regions of the circulation produces a great variety of sudden and surprising effects, which are generally absent after subcutaneous injection of the poison, the comparison of results obtained by the two methods of introduction of venom must be made with a due amount of caution.

III.—Action of Venom on the Blood and Blood Vessels.

Through whatever channel the poison may be absorbed it sooner or later reaches the blood stream, and is distributed thereby through all the tissues and organs of the body. Accordingly it is necessary to ascertain in the first place what changes it may occasion in the blood itself. Without such knowledge it would be impossible to differentiate those effects produced on the various organs of the body which are to be attributed to the primary operation of the poison from those which are secondary to its interference with the normal constitution of the blood.

When the literature of this part of the subject is examined, one notices the entirely different results obtained by observers experimenting with various kinds of snake poison. Cobra poison would appear to exert little effect upon the blood, but that it does have some action is evidenced by the fluidity of the latter in the human subject, after death from cobra-bite. Occasionally too, the mucous discharges from the body are stained with blood. These blood changes are however relatively unimportant, and if an animal survives the nervous symptoms it at once passes into a condition of complete health. With the poison of the viperidæ, and to a less extent with that of most colubrines, other than cobras, the

blood and blood vessels are considerably affected. These changes in the blood include both the corpuscular element and the plasma, and also that little known relationship which normally obtains between the blood and its containing vessels.

(a)—Effect of venom on blood corpuscles, in vitro.

Brunton and Fayrer[1] were unable to discover any change in the blood corpuscles of mammalia, when their blood was mixed with a solution of cobra poison in isotonic salt solution, except an occasional crenation of the corpuscles which might have been due to some concentration of the salt solution by evaporation. Ragotzi,[2] however, who has more recently experimented with cobra venom, found that it produced considerable changes on the corpuscles. He says—"Säugerthierblut war stets verändert, sei es, dass man das Gift subcutan injicirt hatte oder eine Giftlösung dem Blüte zusetzte. In beiden Fällen war die Tendenz zur Rollenbildung vollkommen verschwunden. Die Blutkörperchen waren nur zum geringeren Theil normal. Die meisten hatten ihre biconcave Gestalt mit einer biconvexen vertauscht. Diese Veränderung trat augenblichlich ein, wenn man einer normalen Blutprobe unter dem Mikroskop ein Tröpchen Giftlösung (in 0 6% NaCl) zusetzte. Eine vollständige Auflösung der Säugethier blutkörperchen durch Zusatz von Najagift kam erst nach mehreren Stunden zu Stande.

Setzte man dagegen zu einer normalen Froschblutprobe etwas Gift zu, so blassten fast augenblicklich die körperchen ab: das stroma wurde vollkommen unsichtbar bezw. aufgelöst. Der Kern blieb noch einige Zeit erhalten. Das aufgelöste Blut besass zunächst noch die oxyhämoglobinstreifen, doch verschwanden dieselben nach einiger Zeit, während die Lösung noch ihre rothe, klare Farbe beibehielt (die zum Zusatze verwendete Giftlösung reagirte vollkommen neutral)."

---

[1] Proc. Roy. Soc. Lond.

[2] Virchow's Archiv. Bd. 122, s. 230.

Weir Mitchell and Reichert[1] found that in a drop of mammalian blood mixed with "a minute quantity" of crotalus venom the activity of the leucocytes absolutely ceased. The red corpuscles lost their biconcave form and became spherical and sticky, so that they adherred together in strings. Ultimately the haemoglobin dissolved out and they became invisible. When pigeon's blood was subjected to the action of the venom, the nuclei of the corpuscles appeared to undergo a rapid necrotic change, which finally gave rise to a granular albuminoid material which was seen floating in large quantities between the corpuscles.

Feoktistow[2] who worked with the venoms of *Crotalus* and *Pelias berus* found that 2% solutions of these venoms produced dissolution of the corpuscles after 18 – 24 hours.

The first animal the blood of which I submitted to the action of *Pseudechis* venom was the frog. A drop of frog's blood was mixed with an equal bulk of a ·7 solution of NaCl containing ·1 of venom. The mixture was made on a slide, and speedily covered with a cover glass and the edges smeared with oil to prevent concentration of the salt solution by evaporation. Within a few moments a disintegration of the red cells occurred. They lost their shape, their nuclei became apparent, and the haemoglobin dissolved out; afterwards they appeared larger and circular, and became more and more indistinct, until finally nothing could be seen of them, but shrivelled granular nuclei. These shrivelled nuclei soon began to swell, the granules became less distinguishable and eventually disappeared. The disappearance of the red cells was so complete that at the end of fifteen minutes there was nothing except the slight colouration of the field, to distinguish the preparation from one of lymph.

The action on the white cells was much slower. For the first fifteen minutes I could discover no change in them, but they

[1] *Loc. cit.* p. 143.

[2] "Ueber die Wirkung des Schlangengiftes auf den thierischen Organismus."—Mémoires de l'Acad. imp. d. Sc. de S. Pétersbourg, VII.e Série, Tome XXXVI., No. 4.

exhibited no amœboid movements. At the end of this time the nuclei in some of them were very distinct, as if fixed by acetic acid. They then became intensely granular, and soon began to swell and their outlines to grow less distinct until they disappeared, leaving a small heap of granules to mark their grave. During this time, control specimens situated under similar circumstances showed no change, and the leucocytes were exhibiting active amœboid movements.

The action of the poison on the corpuscles of pigeon's blood is similar to the above, but the dissolution of the red cells, with poison of this concentration proceeds more slowly.

The blood corpuscles of different mammals present remarkable diversity in their power of resisting the destructive effects of the venom. Dog's blood is much more sensitive to this action of the venom than that of any other animal I have experimented with. The readiness with which the corpuscles of this animal are destroyed approaches that of the frog.

Some idea of the small quantity of venom which is necessary to determine the destruction of the red corpuscles of dogs may be gathered from the fact that if 1 c.c. of fresh defibrinated blood be mixed with an equal volume of ·9% NaCl solution containing ·000002 gramme of venom, and allowed to stand for four hours at the temperature of the laboratory (15° C.) the serum which covers the corpuscles becomes deeply stained with haemoglobin, and if a little of the sediment be examined under the microscope, numbers of crystals of haemoglobin are to be seen, together with some corpuscles. A control specimen under similar circumstances, except that the salt solution contained no venom, showed the corpuscles to be well preserved and the serum was only slightly tinged with haemoglobin.

If the concentration of venom in the solution be increased, or the blood be kept at body temperature, the haemoglobin dissolves out much more readily, and in a few hours no corpuscles can be found.

Haemoglobin which has been dissolved out of the corpuscles under the influence of the venom possesses a more than ordinary tendency to crystallize, as is exemplified by the following experiment:—10 c.c. of defibrinated blood of a dog were poured into a dry test-tube containing ·0001 gramme of venom, and placed in an incubator at 38° C. over-night. When examined in the morning the contents of the tube were solid with haemoglobin crystals, so that the mass could only be removed with a spoon. The haemoglobin in the crystals was in part converted into methaemoglobin. A solution of well washed crystals showed the absorption spectrum of methaemoglobin as well as oxyhaemoglobin, so that it would appear that both derivatives of haemoglobin were present together in the crystals. As time went on, the amount of oxyhaemoglobin in the crystals diminished and that of methaemoglobin increased.

This conversion of oxyhaemoglobin into methaemoglobin does not occur under the influence of the venom itself but is due to organisms. It occurred in all the control tubes which were not sterile, but took place in these much later than in those that contained venom. This is probably to be explained by a much greater growth of the organisms in the blood which had received a small admixture of venom. I shall presently show that venom destroys the power possessed by normal serum to inhibit the growth of some micro-organisms, which would explain why they should grow more readily in those test tubes to which venom had been added.

The process of corpuscle destruction can be observed on a warm stage under the microscope, in the same way as with frog's blood. When mixed with salt solution containing ·01 % of venom the field is markedly coloured with haemoglobin after thirty minutes. In two hours the corpuscles are largely destroyed, and in ten hours have entirely vanished and numerous crystals of haemoglobin are seen. They do not swell up, but become globular, the haemoglobin passes out of them and the stromata become less and less distinguishable until they can no longer be discerned.

As I shall presently point out the same extensive destruction of corpuscles occurs when the venom is injected into dogs in quantities of ·0001 gramme per kilogramme of the animal's weight or even less. The lowest limit of concentration necessary to produce this destruction is about the same both within the body and *in vitro*, viz.:—·00001 gramme of venom per 100 C.C. of blood.[1]

The corpuscles of rabbits, guinea-pigs, cats, and white rats are much less easily destroyed by the venom than those of dogs, and human blood is particularly resistant to its action. A concentration of venom of ·005% produced no destruction of corpuscles in my own blood, even when this was kept at body temperature. When the strength of the venom was increased much beyond this amount, disintegration of corpuscles occurred, but proceeded slowly.

The disparity in the amount of blood destruction following injection of the venom into animals of different species, produces a corresponding variation in symptoms, and is associated with a marked difference in their susceptibility to the occurrence of intravascular clotting. Dogs are, weight for weight, about ten times as sensitive to this action of the poison as any other mammal with which I have experimented.

(b)—Examination of the blood of animals after the injection of venom.

The injection of much above a minimum fatal dose of venom produces some destruction of red corpuscles in every animal with which I have experimented. When dogs are the animals used, however, destruction of red corpuscles is very considerable even with one-fifth a minimum fatal dose, and the escaped haemoglobin presents the same increased tendency to crystallize as I have described to be the case *in vitro*. The haemoglobin crystallizes even within the body. The urine nearly always contains such crystals, and on three occasions an animal has died two or three days after the injection of the poison with suppression of urine, and micro-

[1] In arriving at this conclusion I have assumed that one-thirteenth of the animal's weight consisted of blood.—(Welcker)

scopic examination of the kidneys has shown the tubules to be completely blocked with haemoglobin crystals.

Haemoglobinuria is a frequent symptom with animals of other species, except with minimal or sub-minimal doses.

Professor Halford and Dr. Ralph many years ago noticed changes in the corpuscular elements of the blood of animals which had died from the bite of the Australian tiger-snake *(Hoplocephalus curtus)*. Their attention was particularly drawn to the enormous number of leucocytes together with granular debris present under these circumstances. They described the leucocytes as frequently heaped together like masses of grapes. Halford also described some large transparent nucleated cells which he found in the blood of animals eight to twelve hours subsequent to death from snake-bite, but which were not present immediately after that event. Halford at one time attached considerable importance to these cells, which are indeed swollen leucocytes, the condition of which must be attributed to post-mortem phenomena. They are, moreover, as was first pointed out by Dr. Ralph, of Kew, Victoria, also seen in the blood of animals poisoned by prussic acid, when it is examined at a similar interval after death and cannot therefore be considered as patho-gnomonic of snake poisoning.

On examining the blood of animals, immediately subsequent to death from the injection of *Pseudechis* poison I have, except in those cases which have succumbed within a few hours after the injection, always found increase in the number of leucocytes and the occasional gathering together of these in grape like masses.

(c) —Observations on the number of corpuscles after injection of venom.

To obtain a measure of the extent to which the red cells are destroyed, and also of the progress of the leucocytes, under the influence of *Pseudechis* poison, I have made a series of observations on the number of both the red and the white corpuscles present in the circulating blood before, and at different periods subsequent to the injection of the poison.

The animals used were dogs and in all cases the number of the red corpuscles was diminished. The diminution commenced directly the poison reached the circulation, and progressed to such an extent that in some cases the number of the red cells was reduced within a few hours to less than one half of that originally present.

As regards the leucocytes, I expected to obtain evidence of some degree of leucocytopenia immediately following the injection of the poison, and preceding the onset of the leucocytosis which had been observed in the later stages of poisoning. I was surprised however to find that when the venom was introduced directly into the circulation a great decrease in the number leucocytes, amounting in many cases almost to their complete disappearance, occurred immediately after the injection. This disappearance of the leucocytes from the circulating blood was, however, only temporary, and, in a time varying from one-half to five hours, their number in samples of blood slowly increased until it reached and often far exceeded the quantity originally present. I have always observed this extensive diminution in the number of the leucocytes in those cases where the poison was introduced directly into the circulation.

Such a sudden disappearance of leucocytes from the circulation is not, however, peculiar to snake venom. A precisely similar result has been observed to follow the intravenous injection of peptone (albumoses), and Sampson Himmelstjerna,[1] a pupil of Alexander Schmidt, attributed the diminished coagulability of peptone blood to this absence of leucocytes. Lowit[2] and Wright[3] have also drawn attention to the same fact. Both of these authors were of opinion that the diminution of leucocytes was to be accounted for by active leucolysis. Leucocytes are, however, not disintegrated *in vitro* by solutions of venom or of peptone of much greater concentration than they would ever encounter in the circumstances under which these bodies were injected into the veins.

[1] Inaug. Diss. Dorpat., 1882.
[2] Stud. zur Physiol. u Path. des Blutes, Jena, 1892.
[3] Proc. Roy. Soc. Lond., Vol. LII., 1893.

Rieder[1] has, on the other hand suggested, and Bruce[2] has adduced evidence to show, that these cells are not destroyed but only temporarily withdrawn from the circulation, and are to be found crowding the tissues of the liver, lungs, and medulla of bone. A similar temporary disappearance has also been found to follow the intravenous injection of a variety of other bodies among which may be mentioned nucleo-albumens,[3] nuclein,[4] tuberculin,[5] bacterial proteins,[6] and carmine in suspension.[7] With all these bodies the leucocytopenic phase is soon followed by one in which the number of leucocytes is increased.

The cause of this disappearance of leucocytes after intravenous injections of venom, I am inclined for the following reasons to attribute to their collection in the tissues, and not to their rapid destruction :—

(1) Solutions of venom one thousand times as strong as any they could possibly come in contact with in the blood-stream, under the conditions of the experiment, exert no disintegrating effect upon them *in vitro*.

(2) It is almost inconceivable that the rapidity of their disappearance and reappearance can be explained, if one supposes them to be destroyed. In one of my experiments, a sample of blood taken immediately after the venom injection was so devoid of white cells, that it was necessary to search through many hundred squares of the haemocytometer in order to find one ; whereas a a sample of blood taken fifteen minutes after from the same animal contained nearly as large a number as was found previous to the injection.

(3) Sections of the organs especially the liver and lungs appear to contain an excessive number of leucocytes. (I have not made any accurate quantitative observations.)

---

1 Beiträge z. Kenntniss d. Leucocytose, Leipzig, 1892.
2 Proc. Roy. Soc. Lond., LV., 1894.
3 Halliburton & Brodie—Journ. of Physiol., 1894.
4 Horbaczewski, M. f. Chem., Vienna, 1891, Vol. XII., p. 221.
5 Tchistowitsch, Berlin Klin. Woch., 1891, p. 838.
6 Buchner. 7 Werigo, Ann. l'Inst' Pasteur, 1892.

(4) It occurs to a trifling extent only, when the poison is subcutaneously injected.

Sherrington[1] pointed out that most of the substances which when intravenously injected occasion marked leucocytopenia are also lymphagogues. Bayliss and Starling[2] demonstrated that lymph flow was a function of capillary blood pressure and that the latter depends much more upon venous than on the arterial pressure in the region concerned. The injection of venom into the circulation produces an immediate diminution of blood flow, with low arterial and high venous pressures, and it appears to me not improbable that such a condition of diminished flow together with high pressure, is accompanied by greatly increased diapedesis and corresponding decrease of circulating leucocytes. If the animal continues to live, the arterial blood pressure, after an interval of a few minutes, steadily rises and the number of leucocytes in the blood concurrently increases. A mechanical explanation is, however, insufficient, for the introduction of fine particles of carmine produces no alteration in the circulation, but is nevertheless the cause of the collection of leucocytes in internal organs.

The experiments form two series: (1) In which the venom was introduced directly into a vein; and (2) In which the venom was injected subcutaneously.

Enumeration of the corpuscles was accomplished in the following way:—0·5 c.c. of blood just withdrawn from an artery, was sucked up in a carefully graduated pipette and mixed with 99·5 c.c. of an 8% solution of $MgSO_4$ slightly tinged with methyl violet. A few drops of the mixture were placed in the cell of a haemocytometer, and the red corpuscles in ten squares and the leucocytes in one hundred squares of the instrument, counted by two observers. The numbers counted by each observer usually agreed fairly well, and the numbers given in the protocols are the means of the two

---

[1] Proc. Roy. Soc. Lond., LV., p. 197.

[2] Journ. of Physiol. XVI., 1894.

[3] The number of corpuscles in ten squares multiplied by ten thousand gives the number in one cubic millimetre of blood.

observations. In those few cases where there was any marked disagreement, two more counts were made, and the average of the whole four observations was adopted.

Protocols of Series I.

Ex. I.—Slut, weight 6·8 kilos. ; grain 1 of morphia acetate subcutaneously injected.

4·10 p.m., samples of blood drawn.
4·20 „ ·000025 gramme of venom per kilo. of body-weight injected into jugular vein.
4·35 „ same quantity injected.
4·55 „ same quantity injected.
4·57 „ sample of blood drawn.
7·35 „ sample of blood drawn.
10·0 „ sample of blood drawn.

Number of Corpuscles.

Time.	Red in 10 squares.	White in 100 squares.
Before injection of venom	540	24·5
37 minutes after first injection of venom...	466	3 5
3 hours 15 minutes, do. do. do. ...	296	2
6 hours do. do. do. ...	254	17

Ex. II.—Dog, weight 8·2 kilos.; 2 grains morphia acetate.

3·50 p.m., sample of blood taken.
4·0 „ ·000025 gramme of venom per kilo. of body-weight injected into jugular vein.
4·10 „ sample of blood drawn.
4·20 „ sample of blood drawn.
5·0 „ ·0001 gramme per kilo. injected.
6·0 „ sample of blood drawn.
9·0 „ sample of blood drawn.

Number of Corpuscles.

Time.	Red in 10 squares.	White in 100 squares.
Before injection	603	10·5
10 minutes after injection ..	517	·5
20 minutes after injection ...	497	1·5
2 hours after injection	414	7·5
5 hours after injection	365	12·5

Ex. III.—Dog, weight 15 kilos.; 2 grains of morphia acetate injected subcutaneously.

12·35 p.m., sample of blood drawn.

12·40 „ ·000025 gramme of venom per kilo. of body weight injected into jugular vein.

12·55 „ sample of blood drawn.

1·0 „ ·00005 gramme venom per kilo. injected.

1·15 „ sample of blood drawn (coag. 38 mins.)

1·20 „ ·00005 gramme venom per kilo. injected.

1·22 „ dead.

Number of Corpuscles.

Time.	Red in 10 squares.	White in 100 squares.
Before injection of venom ...	684	21
15 minutes after injection ...	550	16·5
35 minutes after injection ...	504	14·5

Ex. IV.—Dog, weight 10·3 kilos; 2 grains morphia acetate injected subcutaneously.

12·50 p.m., sample of blood drawn.

1·0 „ ·000025 gramme venom per kilo. of body weight injected into jugular vein.

1·10 „ sample of blood drawn.

2·0 „ sample of blood drawn.

3·0 „ sample of blood drawn.

4·0 „ sample of blood drawn.

5·0 „ sample of blood drawn.

Number of Corpuscles.

Time.	Red in 10 squares.	White in 100 squares.
Before injection	564	15
10 minutes after injection ...	483	1
1 hour after injection	421	6·5
2 hours after injection	369	3·5
3 hours after injection	322	10
4 hours after injection	297	15·5

I next made some observations on the number of red and white corpuscles in animals which had received a much larger quantity of venom, but in which the poison was subcutaneously introduced. The amount given was such that some of the animals recovered, while others succumbed. The experiments show the same diminution in the number of red corpuscles. The quantity of white corpuscles increased almost immediately after the injection of the poison. The leucocytosis reached a maximum on the second or third day of illness, when the leucocytes were often present in four or five times the normal amount. The number from this time onward gradually decreased, but the leucocytosis persisted to some extent, in the single case in which observations were taken over so long a period, for a fortnight after the complete recovery of the animal.

The number of the red cells was least, twenty four to thirty-six hours after the introduction of the poison, at which time they were reduced to about one half their normal number. This decrease in red corpuscles was associated with the passage of a large quantity of haemoglobin into the urine. The urine often had the appearance of blood, but contained few or none of the red cells. The bile also, in those cases which died contained haemoglobin.

Series II.

In these experiments 5 cub. m.m. of blood were taken from the ear and mixed with 995 cub. m.m. of the $MgSO_4$ solution and the corpuscles counted as before.

Ex. I.—Dog, weight 7·7 kilos.

Sep. 21, 11·25 a.m., sample of blood taken.

" 11·30 " injected subcutaneously in lumbar region with ·023 gramme venom.

" 12·0 " sample of blood taken.

" 3·0 p.m., sample of blood taken (urine contained haemoglobin).

" 5·0 " sample of blood taken (walks with difficulty).

Sept. 22, 8·30 a.m.,(more lively, had passed half a pint of haemoglobin stained urine during night).

„ 12·0 mid-day, sample of blood taken, (drank one pint of milk, diarrhœa).

„ 23 (lively, runs about, drinks plenty of milk, urine contains haemoglobin).

„ 12·0 mid-day, sample of blood taken.

„ 24, „ (quite lively but weak, urine contains haemoglobin; eats well), sample of blood taken.

„ 25, „ (urine contains haematin and albumen), sample of blood taken.

„ 26, „ apparently well, urine albuminous, sample of blood taken.

„ 27, „ (urine albuminous), blood examined.

„ 28, „ (urine contains a trace of albumen), blood examined.

„ 29, „ urine normal, blood examined.

Oct. 1, „ blood examined.

Number of Corpuscles.

Time.	Red in 10 squares.	White in 100 squares.
Before injection	583	20
30 minutes after	503	18·5
3½ hours after	427	36
5½ hours after	365	43·5
1 day after	202	46·5
2 „	217	65
3 „	197	80
4 „	237	73·5
5 „	264	79
6 „	294	54
7 „	342	48·5
8 „	346	49
10 „	358	48
14 „	402	39

Ex. II.—Dog, weight 11·5 kilos.

11·25 a.m., sample of blood taken.

11·30 a.m., ·0065 gramme venom injected in lumbar region.

1·0 p.m., sample of blood taken.

3·30 „ sample of blood taken.

5·0 „ sample of blood taken.

Number of Corpuscles.

Time.	Red in 10 squares.	White in 100 squares.
Before injection	540	12
1½ hours after	492	15
4 hours after	441	31
5½ hours after	402	33

Ex. III.—Dog, weight 11·2 kilos.

Sept. 29, 10·30 a.m., sample of blood taken.

„ 10·35 „ ·01 gramme venom injected in lumbar region.

„ 5·0 p.m., sample of blood examined (had vomited, and passed urine stained with haemoglobin).

„ 30, 10·0 a.m., sample blood taken, (very ill, refuses food but drinks eagerly; can walk with difficulty. Urine contains haemoglobin).

Oct. 1, 10·0 a.m., sample of blood taken, (condition the same).

„ 2, „ sample of blood taken, (condition worse, urine intensely coloured by haemoglobin). The dog died during the day.

Number of Corpuscles.

Time.	Red in 10 squares.	White in 100 squares.
Before injection	548	16
7½ hours after	367	34
24 „	287	57
48 „	245	67
72 „	203	83

Ex. IV.—Slut, weight 8·4 kilos.

10·0 a.m., sample of blood taken.
10·30 „ ·01625 gramme of venom subcutaneously injected in lumbar region.
11·50 „ (very drowsy, vomited, shivering).
12·30 p.m., sample of blood taken.
3·30 „ delirious, temperature 99·4, heart irregular.
4·0 „ sample of blood taken, (comatose).
6·0 „ (comatose, temperature 95·6)
8·0 „ sample of blood taken.
9·0 „ (comatose, temperature 90·3).
10·0 „ died.

Number of Corpuscles.

Time.	Red in 10 squares.	White in 100 squares.
Before injection	546	15·5
2 hours afterwards	471	25
5½ hours afterwards	382	27·5
9½ hours afterwards ...	361	31·5

I have mentioned that venom, when mixed with blood on a slide prevents the display of amœboid activity on the part of the white cells. That the same interference with the vital activity of the leucocytes occurs in the body is shown by the following experiment, which is one of a series with similar results.

Two small pieces of sterilised sponge about 1 m.m. cube were aseptically introduced into the abdominal wall of a guinea-pig. One of these little sponges had been soaked in a ·7% solution of NaCl containing 1% of venom, the other in the saline without the venom. Both sponges were pushed about a centimetre away from the incision, which was afterwards drawn together by a horse-hair suture, and covered with collodion. After two hours a swelling arose round the venom-containing sponge, whereas the other remained of the original size. At the expiration of five hours the animal was killed and both sponges very carefully withdrawn and plunged into absolute alcohol.

Sections of the two sponges treated in the same way presented very different appearances. The control was infiltrated with leucocytes which stained well with ordinary nuclear stains; the other contained leucocytes only near the margins, and many of these were broken down and took the stain badly, or not at all.

From these sponge experiments I conclude that whereas into the control sponge the leucocytes could by their amœboid movements penetrate unharmed, in the other their activity was paralysed, they succumbed, and were eventually disintegrated by the solution of the venom.

To recapitulate: the effects of the venom when introduced into the body on the blood corpuscles are:—

(1) More or less destruction of the red corpuscles, the haemoglobin of which escapes by the urine.
(2) A great increase in the number of leucocytes which may be preceded by a certain amount of diminution.
(3) Inhibition of the vital activity of those white cells which come into contact with the venom in sufficient concentration.

Alterations in the blood-plasma after the injection of venom.

In the previous section of this paper I have shown that venom exerts a destructive action upon the red blood corpuscles whereby their disintegrated products are set free in the plasma. The haemoglobin circulates in solution in the plasma and is eventually discharged by the urine and bile. I do not know that there is any evidence that haemoglobin exercises any baneful influence by its presence in plasma, and I have not noticed any ill effects to follow the injection of two or three grammes of well washed crystals, dissolved in ·9% NaCl solution, into the circulation of dogs. The remaining portion of the red blood corpuscle, the stroma, consists of a highly complex substance which by various methods of handling may be made to yield products which are not so innocent.

By extraction with various solvents, stromata yield cholesterin, lecithin, a globulin, and a proteid compound of nuclein, which is

compared by Wooldridge,[1] who first separated it from stromata, to the substance found by Plosz in liver cells, and named by him nucleo-albumen. Wooldridge refers to this body as—"Ein Eiweisskörper der mit einem anderen an phosphor reichen molecül verbunden ist." He came to this conclusion from the fact that by digesting this body with gastric juice, peptone, and a phosphorous-containing body which he compares with Miescher's nuclein, were formed.

It would be an unwarrantable assumption to suppose that when venom is injected into the blood stream, it produces precisely the same decomposition in the stromata as can be effected by extracting blood corpuscles with ether, alcohol and sodium chloride solution outside the body. Nevertheless we have evidence, as will be seen shortly, that bodies of the nature of nucleo-albumens are under these conditions the part result, and that some of the changes which the plasma undergoes, after the introduction of snake venom into the circulation, are to be attributed to the presence of these particular products of the disintegration of the red corpuscles.

Effect on the coagulability of dog's blood.

In the general enquiry, I have frequently had occasion to use such methods as are commonly employed for obtaining graphic records of the blood pressure in arteries and veins, and have been struck with the remarkably satisfactory manner in which the blood has behaved as regards clotting. On more than one occasion a tracing of the venous pressure in a dog has continued for some hours, without coagulation occurring in the cannula.

This behaviour suggested some inhibition of the normal clotting power of extravascular blood. During several experiments, I accordingly drew samples of blood. In all of these coagulation was retarded, the specimens clotting only after the lapse of one to twenty hours, or not at all. At this time I was working with

[1] Du Bois Reymond's Archiv. 1881, p. 387.

the intravenous injection of very small quantities of the poison, viz.—0·00001 to 0·00002 gramme per kilogramme of body weight.[1]

I am aware that such an observation on the fluidity of the blood, following the introduction of snake poison into the system, is by no means new.

Fontana,[2] more than one hundred years ago, noticed that the blood remained fluid in animals dead of viper bite, and Brainard,[3] writing forty years back, states, that when death occurred *immediately* (the italics are mine) in animals bitten by rattle snakes, the blood was found at the post mortem examination to be clotted, but if some time elapsed before the animal succumbed, the blood remained fluid in the vessels. These observations of Brainard were confirmed by Weir Mitchell[4] in 1860, who explained the difference by the hypothesis that in cases of very rapid death the poison had not had time to affect the blood. A few years later, Halford[5] observed the same continued fluidity of the blood to follow the injection of the venom of some Australian species.[6]

More recently Feoktistow[7] has confirmed Fontana's observation on the condition of the blood after the injection of viper poison (*V. ammodytes* and *V. berus*). The continued fluidity of the blood after death from the bite of the Indian viperine snakes, has been frequently noted during past years by numerous observers in that country, and contrasted with the negative results in this respect following the injection of cobra poison in animals. In death from

---

[1] The weights refer to the poison in the dry condition. The method of acquiring the venom has been described in a previous communication in conjunction with Mr. McGarvie Smith.—Proc. Roy. Soc. N.S.W. 1891.

[2] "Fontana on Poisons," Translated by J. Skinner, London, 1787.

[3] "Smithsonian Reports," 1854.

[4] "Smithsonian Contributions to Knowledge," Vol. XII.

[5] "Medical Times and Gazette," 1873, Vol. II.

[6] Quite recently Dr. Skinner of Beechworth, Victoria, has recorded diminished coagulability of the blood during life, in a case of snake bite which occurred in his practice.—"Australian Medical Gazette," March 15, 1893.

[7] *Loc. cit.*

cobra bite in the human subject the blood is however very frequently fluid, and non-coagulable.

On other occasions, when taking carotid pressure tracings during the injection of larger doses of venom (0·0002 gramme per kilo. or above this quantity), within a minute of the time when the poison was introduced, the record of the rise in pressure due to the heart's beat disappeared, but the pressure in the manometer remained considerably above zero. On investigation it was found that there were no clots in or near the cannula, but in each case the artery, at some little distance from the cannula, contained a solid core of clot extending into the aorta, and left ventricle. On further dissection, the blood in the whole vascular system, excepting only the pulmonary veins and the left auricle, was found to be solid. The clot in the portal venous system was particularly hard. These experiments I have repeated very many times, in fact one or the other phase of coagulability occurs every time this snake poison is injected into a vein of a dog.

Pseudechis venom is not the only kind of snake poison which influences the coagulability of blood-plasma. From the examination of the literature of snake poison in the light of knowledge gained from the above experiments, I felt convinced that some of the results obtained by other observers working with different venoms, which results they attributed to quite other causes, were in reality due to intravascular clotting. Within the last month also, I have had the opportunity of reading a paper by Heidenschild[1] dealing with the same subject. This author found that *Crotalus* venom first raised the tendency of the blood to coagulate, and that this increase was followed by a diminution in coagulability. He was of opinion that an excessive increase of coagulability could occasion considerable thrombosis and the death of the animal. Heidenschild considers that the sudden death from large doses of venom which has been observed by so many experimenters would be explained in this way.

[1] Untersuchungen über die Wirkung des Giftes der Brillen und der Klapperschlange—Inaug. Dissert. Dorpat 1886.

Owing to the fact that Heidenschild's results formed the subject of an inaugural dissertation, and were not as far as I am aware, published in any journal, I had not the advantage until recently of consulting his paper in Sydney, and I regret that on this account I omitted to mention his work in a previous publication of my own on this particular aspect of the physiological effect of the injection of *Pseudechis* venom.[1] We were however, both forestalled by Fontana,[2] who more than one hundred years ago noticed that in those experiments which were followed by the sudden death of the animal, the blood was solid throughout the greater portion of the venous system, and who expressed his opinion that the clotting of the blood in the living animal caused death by arresting the circulation. Fontana, as previously mentioned, also noticed the permanent fluidity of the blood in other cases of viper poisoning, and he would appear to have wondered greatly that two such apparently opposite effects could be produced by the operation of the same agency.

Immediately after the introduction of the venom into a vein, the coagulability of the blood increases, and this increase of coagulability, in the case of moderate or large doses (more than 0·0001 gramme per kilo.), culminates in intravascular clotting of greater or less extent. The smallest dose which I have found to produce complete clotting in the systemic circulation was 0·00015 gramme per kilo. Such a dose, however, usually in dogs gives rise to thrombosis limited to the portal vein and its branches, and inhibition of coagulability elsewhere.

The injection of small doses,—*i.e.* below 0·0001 gramme per kilo.—also gives rise to a condition of increased coagulability of the blood. This increase however, only manifests itself for an extremely short time, and samples must be drawn within two minutes from the time of the introduction of the venom, in order to observe it. This transient positive phase is succeeded by a

---

[1] Journal of Physiology, Vol. xv., p. 380.

[2] *Loc. cit.*—This observation of Fontana's was also unknown to me until quite recently, as a copy of his work was not procurable in Sydney.

negative phase, for blood drawn three minutes after the injection, either fails to clot at all, or does so only after the lapse of several hours. The negative phase continues for one or two days after the introduction of the poison in dogs which have received a nearly fatal dose of the venom subcutaneously.

It is interesting to note that the duration of the phase of diminished coagulability corresponds under such circumstances with the period of blood cell destruction. When this cell destruction ceases, the coagulability of the plasma rapidly returns to the normal. The blood in all parts of the vascular system does not exhibit the same tendency to clot in the vessels. When dogs are the subjects of experiment, coagulation, when present, always occurs in the portal venous system, and the thrombosis is frequently confined to this area. It also occurs more readily with venous than with arterial blood.

Dogs evince varying degrees of susceptibility in this respect, the same dose per kilo. producing in one animal intravascular clotting, in another inhibition of the coagulation of the shed blood.

Results with animals other than dogs.

I have examined the condition of the blood after the intravenous injection of snake poison in rabbits and cats. In these animals both positive and negative phases occur as with dogs. Cats appear more resistant to the action of the venom than dogs and rabbits.

Conditions modifying the effect upon the blood plasma of the injection of venom.

(1) Influence of Respiration.

I have previously mentioned that I have on no occasion observed the blood, which has just traversed the capillaries of the lungs, to participate in an otherwise general thrombosis. Whatever changes may be effected in the plasma during its passage through the pulmonary veins and left auricle, where it remains fluid, are only transient for the blood in the left ventricle and aorta is often solid.

When complete clotting of the blood in both systemic arteries and veins follows injection of the poison, respiration continues

often for a minute or more after the circulation is at a standstill. If records of the arterial blood pressure and of the respiratory movements be taken in these experiments, the moment of clotting in the arteries is indicated on the tracing, by the disappearance of heart-beats, and the straight line described by the style some distance above the abscissa. I have in my possession a number of tracings showing the continuance of respiration for periods up to two minutes after the circulation must have been completely blocked.

These experiments show that as long as the blood will flow through the pulmonary artery and its branches, there is nothing to prevent its normal gaseous interchange, as far as the respiratory movements are concerned. That it takes up oxygen as usual is seen by the colour of the blood in the left heart.

To ascertain whether the modification of the coagulability of the blood during its passage through the lungs depended on its altered gaseous condition, I followed the method which Wright[1] used, to determine the cause of the distribution of thrombosis after injections of Wooldridge's tissue fibrinogen. This observer rendered animals dyspnœic by compression of the trachea previous to the injection of doses, which, as he had determined would, without this treatment, only give rise to a very limited intravascular clotting. The results of injecting "tissue-fibrinogen" into the circulation when in this venous condition were strikingly altered. My experiments were performed on rabbits of like weight. Several were intravenously injected, under exactly similar circumstances, with gradually decreasing doses of venom, until a dose was found which produced a very limited clotting or none at all. Other rabbits of the same weight were then rendered dyspnœic by compression of the trachea continued for one minute before the subminimal dose of venom was introduced. These subminimal doses produced in every case complete clotting throughout the whole vascular system.

---

[1] Journal of Physiology, Vol. XII., No. 2.

Professor Wright has recently extended his observations and shown that it is the increase in CO_2 and not the diminution in the contained oxygen, which determines the greater tendency to coagulate which occurs in venous blood.[1]

(2) Influence of Digestion.

I find I have records of eleven experiments in which 0·0002 gramme per kilo. was injected into the jugular vein of a dog. Seven of these animals died within eight minutes, from extensive venous and arterial thrombosis. Three others died within two hours, and one lived for upwards of four hours. The post mortem examination of this last animal discovered no intravascular clotting, and the shed blood remained fluid until it putrefied. In the three which lived from one to two hours after the injection, there was more or less thrombosis of the portal venous system, but the blood from the rest of the body remained fluid for several hours.

These experiments were not performed with the sole object of observing the effect of venom on the clotting of the blood, and in every one of them records, including one of arterial blood pressure, were taken on a kymograph. Consequently I have in each case the exact time and duration of the injection to refer to. In all the experiments the above mentioned amount per kilo. was dissolved in 2 c.c. of a ·7 % solution of NaCl, and the time occupied by the injection, as registered on the tracing, was from five to eight seconds. The importance of the knowledge that the rate of injection was fairly constant, I shall discuss later on.

At the time of these experiments I attributed the variations in results to idiosyncracies in the dogs. On reconsidering the matter, however, I am inclined to attribute them to the effect of digestion. The seven first mentioned experiments were performed in sequence, and the four last also in sequence. During the former series I was working in the afternoon, whilst the experiments forming the latter series were performed in the forenoon, and I find that the dogs have always been fed at 11 a.m. Thus, for the first series,

[1] Proc. Roy. Soc. Lond., Vol. LV.

dogs which had had a meal three hours previously were used, whereas the last four experiments were made upon animals which had fasted for nearly twenty-four hours.

(3) Influence of Rapidity of Injection.

The variations in effect caused by alterations in the rapidity of injection are very marked. So much so, that it is impossible to compare the results from different experiments, unless the rate with which the poison is introduced is a constant factor. Intravascular clotting is produced most readily if the dose be rapidly thrown into a vein near the heart (*e.g.* the jugular). On increasing the time of delivery of the poison into the circulation, either by employing diluted solutions, or by pressing down the piston of the syringe more slowly, the positive phase (increased coagulability of the blood), is less and less pronounced. If the duration of the injection be still further prolonged, the positive phase, if present, is so rapidly succeeded by the negative variation that this latter appears to be the only result. The negative phase becomes more and more pronounced as larger quantities of the venom are allowed to slowly enter the circulation. For slow injections I have connected a burette containing a very dilute solution of venom in $\frac{7}{8}$ NaCl with the cannula in the vein, by a piece of rubber tube, the calibre of which was controlled by a screw clamp. With this arrangement I have been able to introduce large doses (0·005 gramme per kilo.), without producing intravascular clotting.

The discovery that the effects on the blood plasma after slow injections, are vastly different from, in fact exactly opposite to, those following rapid introduction of the venom, explains why, in my earliest experiments, I did not obtain the same fluid condition of the blood as Halford,[1] who used either subcutaneous injection of the venom, or else allowed a snake to bite the dog. By these methods delivery into the circulation would necessarily be slow, and comparable with results obtained by intravenous injection only in cases in which such injection was very gradually accomplished.

---

[1] *Loc. cit.*

(4) Influence of previous injection of the venom into an animal, on the result of a subsequent injection.

If a small dose of venom (less than 0·0001 gramme per kilo.) be introduced into a dog, the blood, as previously mentioned, exhibits for about two or three minutes after the completion of the injection, an increased coagulability. That is to say, samples drawn during this period clot sooner than control samples taken previous to the injection. At the same time the arterial blood pressure falls to one half or one third of its former height. After twenty or thirty minutes the pressure begins slowly to rise, and thirty minutes to one hour from the time of the injection may have reached or even exceeded its original height. During the whole of this period, with the exception of the first two or three minutes, samples of blood taken from an artery show very marked retardation in coagulation.

If now, one hour or more after the first injection, a second injection containing a much larger quantity (ten or twenty times the first dose) be made, the introduction of this second dose increases the coagulability of the blood during the subsequent few minutes, but samples of blood drawn five or ten minutes after the second injection clot however only after the lapse of several hours, and in many cases spontaneous coagulation is altogether in abeyance. I have always introduced, at the second injection, a quantity of the venom which would inevitably produce complete arterial and venous thrombosis in an animal which had not been previously subjected to an injection of a dose sufficient to establish a negative variation.

On other occasions I have given a dog yet a third injection, containing comparatively speaking, a very large dose, viz.:—·002 gramme per kilo. This amount, dissolved in 3 c.c. of ·7% NaCl solution was injected, as rapidly as possible, into the femoral or jugular vein. This third injection failed to produce any increased coagulability of the blood, and the samples drawn immediately after the injection did not clot at all.

It would thus appear that the establishment of a negative variation confers an immunity, as far as intravascular clotting is concerned, against further injections of the venom. This immunity is very speedily produced; how long it may last I am at present not in a position to say.

These facts explain how it is that one can introduce large quantities of the venom into the circulation, provided this be done slowly, without producing intravascular clotting. The first portion of the injection causes a transitory positive phase, *i.e.*, increased coagulability, but not sufficient to cause actual thrombosis. This is immediately superseded by a negative phase and the establishment of this inhibitory phase confers immunity against the remainder of the injection.

Before discussing the bearings of these facts, I shall indicate the results of an examination of shed blood which has been subjected to the action of the venom, and of some of the reactions of the non-coagulable blood, itself.

Action of a solution of venom on the coagulation of shed blood.

To determine whether a solution of venom were capable of exerting any influence upon shed blood, I dissected out three inches of the femoral artery of a dog, and bled from this directly into a solution of the poison. The cut end of the artery was immersed in a ·9% solution of NaCl, containing 0·1% of venom. By relaxing the compression of the fingers, a small amount of blood—equal to the volume of the salt solution—was allowed to flow into the vessel. The two fluids were at the same time freely mixed by agitating the end of the artery. The blood began to thicken in fifty-six seconds, but clotting did not proceed in a normal manner. At the end of an hour, a small soft clot formed, which on shrinking failed to entangle all the corpuscles. The vessels containing the mixture of blood and venom solution could at no time be inverted without upsetting the contents, as could be done to the vessel in a control experiment with salt solution alone.

On no occasion have I been able to prevent coagulation altogether, as was done by Weir Mitchell and Reichert[1] with the venom of the rattle-snake. These authors drew the blood directly into a vessel containing a solution of venom (a stronger solution than mine), surrounded by a freezing mixture. On allowing the temperature of the blood to rise gradually they found it remained permanently fluid.

Examination of samples of blood exhibiting the negative variation.

Negative phase blood always shows marked retardation in clotting. The delay is so great in some cases that putrefaction sets in before coagulation has occurred. The loss of coagulability is the more pronounced the greater the amount of venom which has been introduced. There is not the slightest difficulty in producing this negative phase; it is only necessary to introduce the poison sufficiently slowly at first, in order that the initial positive variation may not reach the pitch when intravascular clotting occurs.

The blood of the negative phase takes up oxygen and gives it up in the usual manner, and with the exception of its loss of spontaneous coagulability, and the fact that some of the hæmoglobin is dissolved in the plasma, does not obviously depart from the normal. In my examination of this blood, the corpuscles were separated from the plasma by the centrifuge. The extent to which the coagulability of the plasmas was diminished varied according to the amount of venom which had been introduced, and also, to some extent, according to the time which had elapsed between the injection of the venom, and the withdrawal of the sample of blood. In most cases I found that the greatest delay in clotting occurred in blood drawn about an hour after the introduction of the poison. By increasing the dose of venom, I have been able to obtain plasmas in which coagulability was diminished to any degree, from slight delay in the onset of clotting, to absolute

[1] *Loc. cit.*

disappearance of spontaneous coagulability. Those samples in which clotting is delayed for a few hours, but which subsequently clot well, I shall refer to as "weak negative phases," while those in which spontaneous coagulation is entirely in abeyance, and which can only be made to clot under a few special conditions, I shall designate "pronounced negative phases," but it must be borne in mind that individual samples show every degree of loss of coagulability between these extremes.

In plasmas which exhibit only a weak negative phase, clotting can be induced more or less readily by the addition of the following

(1) Solution of nucleo-albumen (Wooldridge's tissue-fibrinogen).
(2) Calcium chloride.
(3) Dilution.
(4) Passage of CO_2 through the liquid.
(5) Alexander Schmidt's fibrin ferment.

These are arranged in the order in which they are most active. As the negative phase becomes more and more pronounced, they lose their capacity to hasten or occasion clotting usually in the inverse order, although exceptions are not infrequent. In a really pronounced negative phase, each and all of these additions are incapable of inducing coagulation.

Such plasmas contain fibrinogen, for by heating, after previous neutralisation, they yield a considerable precipitate at 55° C. The fibrinogen would appear, however, to be present in a somewhat altered condition, for it is now no longer thrown out of solution by half saturation with NaCl.

These plasmas although absolutely devoid of spontaneous coagulability, can be made to yield fibrin, though the amount yielded appears to me to be very much less than that obtainable from an equal quantity of blood plasma, previous to the injection of the poison; but as I have not made any quantitative determination of the amounts, I am unable to speak with certainty on this point.

Plasmas which have lost all spontaneous coagulability may however be made to clot by the following means—

(1) Addition of a saturated solution of NaCl up to an equal volume.

(2) Addition of an equal volume of a saturated solution of $MgSO_4$.

(3) Addition of acetic acid, until the plasma is just faintly acid.

(4) Similar addition of weak sulphuric, hydrochloric, or phosphoric acids. (Oxalic acid is ineffectual).

The addition of the saturated solutions of NaCl and $MgSO_4$ occasions a faint turbidity, and the plasma clots on standing a few minutes. The acids must be carefully added, just to acidification, when turbidity occurs. Until this point is reached, no clotting ever occurs, and if too much be added, the fibrinogen is precipitated. This precipitate readily redissolves in excess of the acid, and when so redissolved I have never succeeded in producing coagulation. The fibrin formed under these circumstances has all the appearance of ordinary fibrin. It is insoluble in weak saline solutions, or dilute HCl (·2%), but swells up in the latter. On digesting with pepsin it dissolves, leaving a perfectly clear solution.

Since the observations of Arthus and Pagés[1] the influence of calcium in coagulation has been recognised to be of the highest importance. Blood, decalcified by drawing it into a solution of a soluble oxalate, or fluoride (Arthus and Pagés), has lost its capacity to clot, although this may be restored by the further addition of calcium salt. The intravenous injection of sodium oxalate (Halliburton and Brodie),[2] or soap (Munk), also renders the blood incoagulable. Pekelharing[3] is of opinion that the diminished coagulability of blood after the intravenous injection of peptone and sometimes of nucleo-albumens is to be explained in the same way.

[1] Archiv. de Physiol., Ser. v., T. II., 1890, p. 739.

[2] Journal of Physiology, Vol. XVII., 1894.

[3] Centrbl. f. d. Med. Wiss., Bd. 45, 1892.

As the fluid plasma of the negative phase after venom injections presents, in many respects, the closest analogies with the plasmas obtained by both of these means, I made a series of experiments to determine the influence of calcium on the coagulability of the blood of animals after injections of venom. The effect of calcium salts on plasmas in vitro, has already been mentioned.

I found that the results of these experiments could be arranged in three classes—

(1) The cases where only a very moderate negative phase has been produced, and the clotting of the shed blood is delayed from thirty minutes to two or three hours.

(2) Cases in which the negative phase is more pronounced and the shed blood clots only after some hours or days.

(3) Very pronounced negative phases in which the blood never clots spontaneously, and in which the addition of saturated solution of sodium chloride etc. only occasions a very small amount of coagulum.

The addition of a few drops of calcium chloride to a sample of blood from the first class, causes almost immediate solidification and if a few cc. of a 1% solution of this salt in ·9% NaCl be injected into a vein, the coagulability of the blood is raised above the normal, and very frequently the animal dies in a few minutes from extensive thrombosis.

With the second class, the calcium chloride is without influence upon the extravascular plasma, but raises the coagulability of the circulating blood towards the normal.

With the third class, $CaCl_2$ has no effect either when injected or added to the plasma in vitro.

The following three experiments, chosen from a large number, illustrate these effects of calcium salts. In these experiments the carotid artery and jugular vein were dissected out, and cannulæ tied in both. The former was used for taking samples of blood, and the latter for the introduction of the venom and calcium

chloride solutions. After the withdrawal of each sample of blood from the artery, the cannulæ was carefully cleaned out.

Experiment I.—Dog, weight 4·8 kilogrammes.

11·45 a.m., 0·13 gramme of morphia acetate subcutaneously.

12·30 p.m., ·000025 gramme venom per kilo. of body weight (dissolved in 5 cc. of ·9% NaCl solution) injected slowly into jugular vein.

1·0 ,, ·00035 gramme venom per kilo. injected into jugular vein.

1·10 ,, sample of blood withdrawn. (A)

1·15 ,, 5 cc. of 1% solution of $CaCl_2$ in ·9% NaCl solution injected into jugular vein. This was followed by immediate thrombosis and death.

Sample A centrifugalised.

(1) Plasma clotted alone in thirty-five minutes.

(2) Plasma + 4 drops of ·5% solution $CaCl_2$ clotted almost immediately.

Experiment II.—Dog, weight 5·3 kilogrammes.

11 a.m., 0·13 gramme morphia acetate subcutaneously.

12 p.m., ·000025 gramme of venom per kilo. of body weight in 5 cc. ·9% NaCl solution, slowly injected into jugular vein.

1 p.m., ·00035 gramme of venom per kilo. injected into the jugular vein.

2·45 sample of blood withdrawn. (A)

2·50 10 cc. 1% solution $CaCl_2$ in ·9% NaCl solution injected into jugular.

2·55 sample of blood withdrawn (B), which clotted in five minutes; the clot was a soft one, and never became a firm jelly.

Sample A centrifugalised.

Plasma A clotted slightly and spontaneously after 20 hours.

Plasma + $CaCl_2$, clotted in the same time.

Experiment III.—Dog, weight 14·4 kilogrammes.

11 a.m., 0·15 gramme morphia acetate.

12·10 p.m., ·000025 gramme venom per kilo of body weight in 5 cc. ·9% NaCl solution slowly injected into jugular vein.

2·0 „ ·00035 gramme venom per kilo. injected into jugular.

2·15 „ sample of blood withdrawn. (A)

2·30 „ ·00035 gramme venom per kilo. injected into jugular.

3·0 „ sample of blood withdrawn. (B)

3·10 „ 10 cc. 1% solution of $CaCl_2$ in 9% NaCl solution, injected into jugular.

3·30 „ bled to death. (C)

All the samples of blood were centrifugalised. The plasmas A, B, C clotted under the following circumstances :—

A—Plasma clotted spontaneously in 4 hours 14 minutes

Plasma diluted with water, in 2 hours 30 minutes

Plasma + $CaCl_2$ in 4 hours.

B and C—Plasma did not clot spontaneously, nor on dilution.

Plasma + $CaCl_2$ no clot.

Plasma + $CaCl_2$ and 1 cc. of nucleo-albumen solution (from testis)—precipitate, which next morning was partially converted into fibrin.

Plasma acidified with acetic, hydrochloric, sulphuric and phosphoric acids until turbidity was produced, clotted in less than fifteen minutes.

Plasma + equal volume saturated solution NaCl, clotted in ten minutes.

Plasma + equal volume saturated solution $MgSO_4$, clotted in twenty-two minutes.

As in those cases where the negative phase is well pronounced, calcium is ineffectual in producing coagulation, both in intra- and extra-vascular plasma, it cannot well be maintained, as Pekelharing supposes to be the case with peptone blood, that this disappearance

of clotting power is due to the absence of free calcium salts from the blood.

The analogous behaviour of blood after snake venom injection with peptone blood, is not however, in this respect departed from; for I find that both peptone plasma and the plasma obtained after the slow injection of nucleo-albumens, behave in a manner identical with snake venom plasma, provided a sufficient quantity of these bodies have been introduced to produce a complete disappearance of all tendency to spontaneous coagulation. As Pekelharing's inviting hypothesis only explains the partial phenomena of peptone injection, one cannot accept it as an interpretation of the facts.

Significance of these phenomena.

These phenomena of intravascular coagulation exhibiting positive and negative phases, together with the conditions which I have found to modify the result, show the closest parallelism with the effects observed by Wooldridge,[1] Wright[2] and Halliburton[3] to follow the introduction of tissue-fibrinogen (nucleo-albumen) into the circulation. This parallelism is still further evident when one compares the behaviour of the fluid blood, drawn from an animal poisoned with venom, in which the negative phase is pro-

---

[1] "On intravasc. coag."—Proc. Roy. Soc., 1886. "Ueber intravasc. Gerinnung"—Du Bois Reymond's Arch., 1886. "Uebersicht einer Theorie der Blutgerinnung"—Ludwig's Festschrift, 1887. "On hæmorrhagic Infarction of the Liver"—Proc. Path. Soc. 1887. "The Nature of Coagulation"—Hainsworth & Co., London 1888. "Ueber Schutzimpfung auf chemischem Wege"—Du Bois Reymond's Arch. 1888.

[2] "On the conditions which determine the distribution of the coagulation following the intravascular injection of Wooldridge's tissue-fibrinogen."—Journal of Physiol., Vol. XII, No. 2. "A study of intravascular coagulation produced by the injection of Wooldridge's tissue-fibrinogen."—Proc. Roy. Irish Acad., 3rd Series, Vol. II., No. 2. "On tissue or cell fibrinogen in its relation to the pathology of blood."—Lancet, Feb. 27 and March 5, 1892.

[3] "The proteids of kidney and liver cells."—Journal of Physiol., Vol. XIII., Supplement Number. "The chem. physiol. of the animal cell."—Goulstonian Lectures, lecture 3, B.M.J., March 25, 1893.

nounced, with the reactions which have been found to characterise the blood drawn during the corresponding phase following the intravenous injection of "tissue-fibrinogen."

Wooldridge in one of his papers[1] thus summarises the results obtained by injecting tissue-fibrinogen :—"If a solution of tissue-fibrinogen be injected into a dog in varying quantity, the effects observed are : with very small quantities no discoverable intravascular clotting occurs, but the blood drawn off after the injection clots very slowly, 1 – 2 hours intervening ; with larger quantities intravascular clotting takes place, being, as a general rule, chiefly confined to the portal venous system—the extent of clot being greater as more tissue-fibrinogen is injected. The shed blood (from other areas) will not clot. The more tissue-fibrinogen there has been injected, the more complete is this prevention of the (extravascular) clotting—the interval between the drawing off and the clotting varying from two to thirty hours. In most cases the blood can be readily made to clot firmly by additions, such for instance, as the ordinary fibrin-ferment, and in the great majority of cases it clots firmly on standing."

A few pages further on in the same paper, he says :—"Further, the injection of a very large quantity of tissue-fibrinogen always leads to the production of a shed blood entirely noncoagulable, either spontaneously, or on addition of leucocytes or tissue-fibrinogen. The only difficulty is this, that frequently the circulation is arrested before the required quantity is got in, and then only marked slowing of the shed blood is produced."

A summary of my experiments, showing the effect on the coagulability of the blood from the intravenous injection of different amounts of venom, could well enough be given in the same words as those used by Wooldridge, substituting only, "venom" for "tissue-fibrinogen."

Wooldridge also found that variations in the condition of an animal were followed by alterations in the amount and distribution

[1] "Nature of Coagulation," p. 31.

of the thrombosis, and Wright,[1] in following up the researches of this observer, has very considerably extended our knowledge in this respect, as regards both dogs and other animals.

One of the modifying conditions observed by Wooldridge was that in fasting dogs, unless large quantities of the "tissue-fibrinogen" were injected, the intravascular clotting was limited to the portal area; whereas the same dose given to an animal in full digestion produced clotting extending to the general venous system, right heart, and even into the arteries. I have shown reasons for believing that the blood of animals in full digestion exhibits the same increased sensitiveness towards the action of the venom.

I have previously had occasion to mention an experiment of Wright's, in which he rendered an animal dyspnœic by compression of the trachea before injecting tissue-fibrinogen. Wright found that the injection of an amount of "tissue-fibrinogen" which would, in an animal not so treated, give rise to clotting only in the portal venous system, under these circumstances followed by intravascular clotting throughout the whole vascular system. Similar experiments with venom produced results corresponding, in every case, with those detailed by Wright.

Another experimental condition which influences in an exactly corresponding manner the results from injections of both "tissue-fibrinogen" and venom, is the rapidity with which they are introduced into the circulation. Wright[1] has already drawn attention to this factor as influencing the results from the injection of "tissue-fibrinogen." I have experimented with "tissue-fibrinogen" in order to determine this point, and I find that as I have indicated to be the case with venom, one can produce at will the positive or negative phase by the injection of the same amount of "tissue-fibrinogen," simply by varying the rate at which it is allowed to enter the circulation. Both "tissue-

1 *Loc. cit.*

1 Proc. Roy. Irish Acad., 3rd Series, Vol. II., No. 2.

fibrinogen," and venom may be introduced in great quantity, without increasing the coagulability of the blood, once the initial positive phase is passed, and a negative phase established, if the solution be allowed to flow very slowly into a vein.

In 1888 Wooldridge[1] published a remarkable result he had obtained with the injection of his "fibrinogens" viz.—that the injection of one dose conferred upon the animal immunity from further injections. Exactly the same occurs with the venom. The first injection produces an immunity, as far as the clotting of the blood in the vessels is concerned, from the effects of future doses, even when those are very large.

I have had many opportunities of confirming this statement of Wooldridge. An analogous result has been obtained with the intravenous injection of albumoses, although the effect of these upon the blood is of the reverse order. Schmidt Mulheim[2] found that when the coagulability of the blood had reappeared after it had for the time being vanished owing to a first large injection of albumoses, it was not influenced by a second injection. The first injection must however be a full one or the immunity is not complete.

The parallelism, as far as the coagulation of the blood is concerned between the results of the injection of "tissue-fibrinogen" and of venom, is, as has been pointed out, maintained when one examines the conditions under which the two kinds of fluid blood may be induced to clot.

Both these kinds of blood remain fluid, or clot only after the lapse of some hours, the time intervening before the onset of coagulation depending in both cases on the amount of the agent injected: and by injections of nucleo-albumens and of venom, one can obtain a series of plasmas which, as regards the circumstances under which they may be made to yield fibrin, exactly correspond.

---

[1] "Schutzimpfung auf Chemischen Wege."—Du Bois Reymond's Arch. 1888.

[2] Du Bois Reymond's Arch., 1880, S. 52.

So close is the parallelism between the two series of phenomena, that one is inevitably driven to enquire whether after all there may not underlie both an actual identity of process. But in thus enquiring, one is confronted by the very striking fact that in the venom experiments, only an exceedingly small quantity of the active agent is required to produce an effect negative or positive on the coagulability of the blood.

Wooldridge stated that it required 1·5 to 2 grammes of his "tissue-fibrinogen" to produce intravascular clotting, in a medium sized dog. This I imagine, from my own experiments with "tissue-fibrinogen," is a rather high estimate. However this may be, it is certain that in the one case we are dealing with the injection of grammes, and in the other with thousandths, or ten-thousandths of a gramme. He also found that his "fibrinogen" disappeared in the process of coagulation and presumably took part in the formation of the clot.[1]

On account of the minute quantity of venom required to produce the intravascular clotting, it is hard to conceive that it can operate by any such direct action. An important difference between the two series of phenomena which I have always noticed is, that whereas with injections of "tissue-fibrinogen" the clotting occurs practically instantaneously, so much so, that it frequently causes blocking in the vein before one has had opportunity to finish the injection, with venom injections there is an interval of at least 90 - 100 seconds before clotting occurs in the arteries, but notwithstanding this delay in onset, the clotting in cases of venom injections is much firmer and more extensive than I have ever been able to obtain with "tissue-fibrinogen."

Pekelharing,[2] Wright,[3] and Halliburton,[4] have recently shown that the bodies Wooldridge designated "tissue-fibrinogen" consist largely of nucleo-albumens, and that these nucleo-albumens are the active agents in producing intravascular clotting.

1 "Nature of Coagulation," and "Ueber intravasc. Gerinnung."
2 "Virchow's Festschrift," Bd. 1.
3 "Proc. Roy. Irish Acad." 3rd Series, Vol. II., No. 2.
4 "Jour. of Physiol." Vol. XIII., Supplementary Number.

The venom of the Australian black snake does not contain any body of the nature of a nucleo-albumen. If a clear solution of venom be subjected to artificial gastric digestion, it is quite unaltered in appearance (no precipitate of nuclein). Moreover, by such treatment it is not deprived of its toxic properties.

The question has now to be answered whether, notwithstanding this negative result, there is yet any source from which through the direct or indirect action of the venom (*e.g.* the production of this substance within the organism itself, under the influence of the specific toxic activity of the venom), a sufficient supply of nucleo-albumen could be derived.

I have already shown that this venom is a powerful agent in the destruction of red blood corpuscles, and evidence exists that bodies like ether and tannates,[1] sodium chlorate, glycerin, toluenediamine, arsenic and phosphorus,[2] which when injected into the circulation disintegrate red cells, and occasion haemoglobinuria, also produce thrombosis.

Wooldridge[3] and Nauck[4] produced intravascular coagulation by injecting the stromata of mammalian blood corpuscles, and the similar results of Köhler[5] obtained by injection of the haemaglobin-stained fluid expressed from warm blood clot, may no doubt be explained as due to broken up corpuscles. Krüger has confirmed Wooldridge's results as regards the stromata of bird's blood.

Groth[6] and Krüger[7] have found intravascular coagulation to follow the introduction of a saline extract of lymph-glands, containing leucocytes, into the circulation. Wooldridge criticised these results of Groth and Krüger on the ground that *well-washed*

---

[1] Naunyn, Ueber den neuen Standpunkt in der Lehre von Thrombose.—"Ber. Klin. Woch. No. 24, 1886.

[2] Silbermann—"Virch. Arch., Bd. 117, S. 288."

[3] "Practitioner," 1886. [4] Diss. Dorpat. 1886.

[5] "Ueber Thrombose etc." Inaug. Diss. Dorpat. 1887.

[6] "Ueber die Schicksale der farblosen Elemente im kreisenden Blute." Dorpat. 1884.

[7] "Zeitschr. f. Biologie," Vol. XXIV.

leucocytes have no such effect, and he ascribed the consequences of their injection to the fluid and not to the cells. As nucleo-albumens are set free by the disintegration of cells, Wooldridge would by his washings separate the products of disintegration, whereas Groth and Krüger would inject them.

There is then abundant evidence that the disintegration of both kinds of blood cells outside the body sets free nucleo-albumens, which if introduced into the circulation may give rise to intra-vascular clotting; and also that some bodies which when injected into the blood stream, cause destruction of the red cells, also occasion thrombosis. I am therefore of opinion that the effect of venom on plasma is a secondary one, and due to the presence of nucleo-albumens in the circulation. This opinion is supported by the fact that in two cases, after the injection of a comparatively large dose of venom, in which the shed blood did not clot spontaneously at all, I was able to separate from the plasma, a small quantity of nucleo-albumen.

Five per cent. acetic acid was carefully added to the plasma, until the precipitate, which was at first produced, almost entirely disappeared. This precipitate by acidulation with acetic acid or other weak acids has generally been considered to be fibrinogen. Lilienfeld maintains however, that Hammarsten's fibrinogen is by this means split up into two bodies: (1) "Thrombosin," which invariably clots in the presence of calcium, (2) a proteid, which he regards as an albumose, and which itself, hinders coagulation. "Thrombosin" is readily dissolved by excess of the acid. Nucleo-albumin is not dissolved by this strength of acid.

A few more drops of the acid were then added without dissolving what remained of the precipitate. This was then separated by filtration, and thoroughly washed with water. It was now insoluble in water or dilute saline solutions but dissolved readily in 1% sodium carbonate solution. Five cc. of this solution were introduced into the jugular vein of a rabbit, and in less than a

1 "Zeitschr. f. Physiol. Chem.," Bd. xx.

minute the animal died with complete thrombosis of the whole venous system. Another portion of the precipitate was dissolved in ·2% HCl, and pepsin added, and kept at 40° C. overnight. In the morning there was a precipitate of nuclein in the vessel.

From experiments with "tissue-fibrinogen" which I have quoted in this paper, it will I think be obvious, that if by the action of this agent, the coagulability of the blood is to be so increased as to cause intravascular clotting, it must first be present in the blood in some quantity. Even when large areas of cells are disintegrated, as in pneumonia, the rate of absorption is so slow, that this condition is not usually fulfilled, though Wright has suggested that it may explain the increased coagulability of the blood which has been observed in this disease. The more or less extensive ante-mortem clots which are so frequently found in the right ventricle after death from pneumonia, are probably to be explained in the same way.

It would be quite otherwise, were the nucleo-albumens the product of disintegration of cells in, or in proximity to the blood stream, as the corpuscles or the endothelial cells lining the whole of the vascular system. In such a case the conditions would be practically the same as if these toxic agents were injected from without.

We have already seen that in disintegration of the red corpuscles by the venom, we may have an available source of nucleo-albumens. Moreover, as I shall point out in the next section of this paper, the venom also exerts a destructive action upon the endothelium of the whole vascular system, whence a possible additional supply of these proteids may be derived.

I am not aware of any instance in which sudden death from thrombosis of an extensive character, has in the human subject followed the bite of one of our Australian colubrines. To occasion such an event it would be necessary for the poison to be injected subcutaneously in a very considerable dose, or else for it to be discharged into a vein. The most rapid death of which I have

obtained a record, occurred in thirty minutes after the infliction of the bite. The patient was an adult, and post mortem examination revealed decolourised (ante mortem) clots in the right ventricle with a fluid condition of the blood generally. In this case it would appear that death was directly due to intravascular clotting, and it is possible that thrombosis in smaller areas of the circulation may be responsible for some of the symptoms which occasionally occur.

The fact that after death from poisoning in man the blood is almost invariably fluid, together with the frequent occurrence of hæmoglobinuria in severe cases, shows that the venom produces similar effects on human blood as on the blood of the lower animals; and though these blood changes are not so obvious in the human subject as in the dog, this fact is owing partly to the relatively smaller doses inoculated, and partly to the lesser sensitiveness of the blood of man to the action of the venom.

When small animals, such as birds, rats, mice, and frogs, are bitten by *Pseudechis*, they run about for a period varying from a few seconds to two or three minutes: their breathing then suddenly becomes dyspnœic, and convulsions and death speedily follow. If, just before death they be withdrawn from the cage and opened, the whole venous system and right heart will be found full of clot.

The injection of a virus which occasions a sudden arrest of the circulation is one of the means acquired by this reptile for securing its prey. It would be hard to imagine a quicker or more effectual method. After a small animal has been bitten by a snake, the latter would appear to recognise that it will not have long to wait for its meal. During the interval which precedes the death of the bird or mouse, the snake carefully watches it, and as soon as the little animal is prostrate, proceeds, if hungry, to swallow it.

It is possible that the instances when an agitated bird has been seen to "flutter from a bough, almost into the mouth of a snake," which instances have frequently been mentioned as proof of the reptile's power of fascination, may more correctly be

spoken of as cases in which the bird has been bitten, and the snake is biding his time, until, from the sudden operation of the poison, his victim falls dead beside him.

(*e*)—*The gases of the blood after venom injections.*

The analogy between the fluid condition of the blood which may obtain after the injection of the venom, and its condition subsequent to the intravenous injection of a solution of commercial peptone has been pointed out. It must, however, be borne in mind that this condition is produced in the case of peptone injections only after the introduction of large quantities, *e.g.*, ·3 gramme per kilogramme of body-weight; whereas the amount of venom required to produce the same result is ·00005 grammes per kilo.

It has been shown that after peptone injection, the quantity of CO_2 in the blood is altered. Lahousse,[1] Salvioli,[2] and Blachstein[3] have drawn attention to the fact that the total amount of CO_2 contained in the blood of an animal after the injection of peptone is very considerably decreased. Grandis[4] has also shown that at the same time the actual tension of CO_2 is considerably increased. The CO_2, combined with the sodium carbonate of the plasma is, to a very large extent, carried by the blood from the tissues as sodium bicarbonate. Solutions of sodium bicarbonate at the temperature of the body very readily part with CO_2 to an atmosphere in which the partial pressure of this gas is low. Accordingly in the pulmonary circulation the CO_2 is to a large measure discharged. When the partial pressure of a gas in a fluid is higher than usual, though at the same time the actual quantity of such gas is diminished, the only explanation of the facts is, that the capacity of the fluid to dissolve or combine the gas has been lessened. Salvioli[5] pointed out that the alkalinity of the blood of an animal, injected with peptone, was less than

---

[1] "Du Bois Reymond's Arch.," 1888.
[2] "Arch. Ital. de Biol.," Vol. XVII.
[3] "Du Bois Reymond's Arch.," 1891.
[4] "Du Bois Reymond's Arch.," 1891. [5] *Loc. cit.*

that of the same blood previously; and he indicated the analogy between the effects of peptone on the amount of CO_2 combined in the plasma, and on the alkalinity of the blood, with the results obtained by Walter[1] by the introduction of acids into the circulation. Grandis[2] showed that the decrease observed in peptone blood was due to the diminution in that portion only of the CO_2 which could be withdrawn by the gas pump, and that the amount of fixed CO_2 was the same as in normal blood.

The conclusion arrived at is that peptone diminishes the capacity of the blood to carry away the CO_2 from the tissues. This impediment to the removal of CO_2 has been considered to be the probable cause of the narcosis which invariably follows the introduction of peptone into the circulation. The general features of the narcosis which follows the injection of very small amounts of venom into the circulation, present a striking similarity to this effect of peptone injections. Moreover in those conditions when considerable destruction of blood corpuscles is occurring, the normal alkalescence of the blood has been found to be diminished. In fever (Geppert,[3] Minkowski,[4] and v. Jaksch[5] have recorded that the blood is less alkaline than normally. Kraus[6] examined the alkalescence, and amount of CO_2 contained in the blood after the intravenous injection of pyrogallol, ether, glycerin and other substances which exert a destructive influence on blood corpuscles. In every case he found a considerable diminution in both the **alkalescence and the contained CO_2.**

I have already shown that venom does destroy blood corpuscles, and that as regards the production of intravascular clotting its behaviour is analogous to that of the above mentioned corpuscle-

---

1 Die Wirkung der Salzsäure auf de thierische Organismus.—"Arch. f. exper. Path.," Vol. VII., 1887, p. 148.

2 "Du Bois Reymond's Arch.," 1891, p. 499.

3 "Zeitsch. f. Klin. Med.," Bd. II., S. 355.

4 "Archiv. f. Exper. Path.," Bd. XIX., S. 209.

5 "Zeitsch. f. Klin. Med.," Bd. XIII., Heft 3.

6 "Archiv. f. Exper. Path.," Bd. XXVI., S. 186.

destroying agents, and it appeared to me advisable to ascertain what the amounts and tensions of the gases in the blood of animals poisoned by venom were. I have not made any direct quantitative observations on the alkalinity of the blood under such circumstances, because the determination of this point presents in this case especial difficulties, owing to the fact that the plasma is invariably more or less coloured by the presence of hæmaglobin in solution, so that the range of experimental error is considerable. This is not, however, a very serious omission, for the determination of the amount of CO_2 contained in the blood is after all probably the best indication we possess of its relative alkalinity.

Methods of Experimenting.

The experiments were made upon large dogs, which were previously rendered anæsthetic by the subcutaneous injection of morphia. On two occasions about 30 cc. of blood was drawn; once previous to, and once at an interval after the injection of the venom. For purposes of comparison the first sample was employed to determine the amount of the gases in the normal blood. As the blood drawn subsequent to the injection of venom did not clot, the coagulation of the first sample was prevented by drawing the blood into a suitable amount of 1% potassium oxalate solution, which had been previously boiled under diminished pressure. In order that the results from the two samples should be strictly comparable, the same course was adopted with the blood withdrawn after the venom injection.

The samples of blood were collected over mercury in the usual manner; the connection between the blood vessel and the receiver was filled with the oxalate solution. In most cases the samples were taken from the external jugular vein, but occasionally from the carotid or femoral artery. They were then transferred from the vessels into which they had been drawn, to the exhausted receiver of a mercury pump, containing a small quantity of a solution of oxalic acid. During the exhaustion of the gases from the blood the receiver of the gas pump was maintained at 37° C.

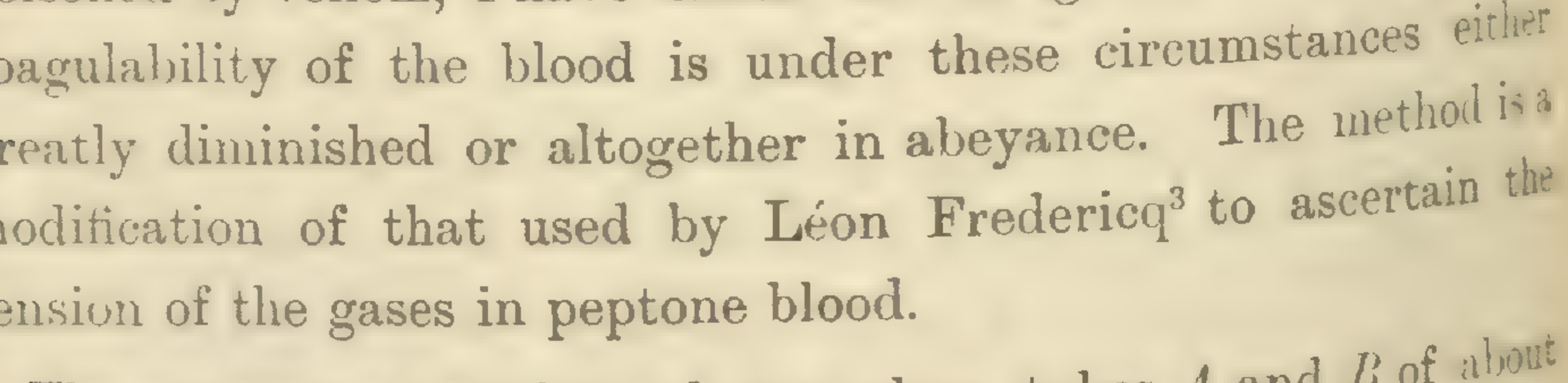
by means of a water bath. The gases were analysed by Bunsen's method, and the quantities found, reduced to their volumes at a temperature of 0° C., and 760 mm. of mercury pressure. In the tables of experiments the amounts of gas are expressed in volumes per hundred volumes of blood.

The determination of the partial pressure of CO_2 in normal blood was not undertaken. The exhaustions, and analyses required to ascertain the absolute amount of gases in two samples of blood, and of the tension in the poisoned blood, together with the other details of the experiment, occupied the entire day, and did not allow time for any further aërotonometric observations.

The averages of the results arrived at by Strasburg[1] and Nussbaum[2] for the tensions of CO_2 in arterial and venous blood for the dog are—2·8% and 4·5% of an atmosphere respectively, and I have used these numbers for purposes of comparison.

In determining the tension of the gases in the blood of dogs poisoned by venom, I have taken advantage of the fact that the coagulability of the blood is under these circumstances either greatly diminished or altogether in abeyance. The method is a modification of that used by Léon Fredericq[3] to ascertain the tension of the gases in peptone blood.

The apparatus consists of two glass tubes *A* and *B* of about 1 c.m. internal diameter and 25 cc.m. capacity. These two tubes



are surrounded by a larger tube through which a current of water at 40° C. is kept circulating. At both ends the tubes *A* and *B* are attached by india rubber tubing to Y shaped glass tubes.

1 "Pfluger's Arch.," Bd. VI., S. 65. 2 Ibid., Bd. VII., S. 296.

3 "Centrbl. f. Physiol.," VII., N. 2.

The third limb of the Y tube is connected in the one case to the central, and in the other to the peripheral end of a vein by means of another rubber tube and suitable cannula. At the end of the instrument which is attached to the central end of a vein a piece of glass tube bent in the shape of a horse-shoe is inserted in the position *h*. Screw clamps *c*, *c'*, *d*, *d'*, are applied in the positions indicated in the diagram.

Before using the apparatus, *A* and *B* were filled, one with air and the other with a mixture of gases containing 5 vols. each of oxygen and carbonic acid and 90 vols. of nitrogen, and all the clamps tightened. The rubber connections between the clamps and the bloodvessels were filled either with blood or salt solution, and the cannulæ tied in their respective vessels. I have found it most convenient to connect the tube (*a*) to the peripheral end of the femoral vein, and the tube (*b*) to the central end of the jugular vein on the same side. The whole apparatus is inclined at a small angle and by relaxing the screws *d* or *d'* and *c* or *c'* and then removing the clamp forceps on the veins, blood is allowed to enter the tube (*a*) and trickle down the glass tube *A* or *B* which contains the mixture of gases, and eventually escape through (*b*) into the circulation again. The horse-shoe shaped tube of glass (*h*) is necessary in order that it may be seen at once if bubbles of air are carried along with the blood and that they may be prevented from entering the circulation. There is after a little practice no difficulty in preventing this accident. The rate of flow of blood through the apparatus could be regulated with nicety by means of the screw clamps *d* and *d'*. Throughout the experiments the loss of heat to the blood which took place during its passage through the rubber tubes was minimised by enveloping these tubes in cotton wool.

As the blood trickles through, it is spread in a thin layer over the interior surface of the tube and so presents a considerable area for gaseous interchange with the mixture of gases above. This interchange proceeds until the partial pressure of the gases in the tube is the same as that of the blood. When a sufficient time

has elapsed for this to occur, the clamps (c) and (d) are tightened and (c') and (d') opened and the blood allowed to flow through the tube b for a similar interval of time. The screw clamps c' and d' are now closed, the clamp forceps replaced on the veins, and the whole apparatus disconnected and placed in a vertical position. By connecting one of the Y tubes with a pressure bottle containing mercury the gas first in A and then in B is driven over into separate burettes and analysed.

Sometimes however, instead of using the apparatus to obtain two estimations of the tension of the gases in venous blood, the Y tube at the upper end of the instrument has been discarded and the two tubes A and B connected with the femoral artery and vein respectively. The procedure has then been exactly the same as described above, but in these latter cases the tensions of the gases both in arterial and in venous blood under the same circumstances were determined. From a few preliminary experiments it was ascertained that the interchange of CO_2 between the blood and the mixture of gases contained in the tube was complete in five minutes when the mixture of gases contained 5% of CO_2 at the commencement of the experiment, and in ten to fifteen minutes when the tube contained air. In the accounts of individual experiments the tension of CO_2 found is expressed in percentage of an atmosphere. The numbers found when the aërotonometer tube was filled with air at the commencement of the experiment are marked (A), those in which the tube contained 5% of CO_2 to begin with are marked B.

In every experiment ·000025 gramme of venom per kilogramme of body-weight was at the commencement injected into the jugular vein. After an interval of one hour an amount of venom varying in individual cases from ·0001 to ·001 gramme per kilo. was further injected. The reason this particular procedure was adopted was in order that the first small injection might produce a sufficiently marked negative phase of coagulability in the blood and that the larger injection might not occasion sudden death by thrombosis.

Experiment I.

Weight of animal.	Condition.	Quantity of venom injected.	Vols. of gases at 0° and 760 mm. in 100 vols. of blood from femoral vein	
			CO_2	O
Kilos. 3·11	Before venom injected	·0065 gramme	38·63	21·30
	1 hour after injection. Blood pressure fairly high, respiration shallower than previously.	...	35·73	19·43

Experiment II.

Weight of animal.	Condition.	Quantity of venom injected.	Vols. of gases at 0° and 760 mm. in 100 vols. of blood from femoral vein	
			CO_2	O
Kilos. 11	Before injection ...	·0105 gramme	44·56	6·35
	30 minutes after injection; circulation and respiration much enfeebled.	...	49·24	4·60

35 - 45 minutes after the injection the tension of CO_2 in the blood from the femoral vein was found to be ... ... A 8·8 % of an atmosphere
45 – 55 minutes after it was ... ... B 9·1 % „
Mean 8·95 % „

Experiment III.

Weight of animal.	Condition.	Quantity of venom injected.	Vols. at 0° and 760 mm. in 100 vols. of blood from femoral vein.	
			CO_2	O
Kilos 5·2	Before injection ...	·001 gramme	40·13	7·73
	30 minutes after ...	...	40·40	—
	2 hours after	...	39·92	9·25
	Respiration and circulation well maintained			

30 minutes after injection tension CO_2 in femoral vein A = 2·63, B = 2·82 } 2·72
45 minutes „ „ „ „
2 hours „ „ „ „ A = 4·03, B = 3·90 } 3·96
2 hours 15 minutes „ „ „ „
2 hours 50 minutes „ „ „ „ A = 3·63, B = 3·78 } 3·705
3 hours after injection „ „ „ „

In this experiment the dose of venom introduced was much less. The animal was in a narcotic condition and the respiration though slow was deep. The blood pressure was normal.

Experiment IV.

Weight of animal.	Condition.	Quantity of venom injected.	Vols. at 0° and 760 mm. in 100 vols. of blood from femoral vein.	
			CO_2	O
Kilos. 6·5	Before injection ...	·0001 gramme	40·23	9·60
	40 minutes after ... Respiration and circulation fairly good.	...	41·24	5·39

1 hour after injection tension of CO_2 in femoral vein A = 6·35 } 6·07
70 minutes „ „ „ „ B = 5·30 }

Experiment V.

Weight of animal.	Condition.	Quantity of venom injected.	Vols. at 0° and 760 mm. in 100 vols. of blood from carotid artery.	
			CO_2	O
Kilos. 14·5	Before injection ...	·005 gramme	39·50	20·26
	20 minutes after injection, respiration and circulation failing.	...	43·42	12·44
	2 hours 20 minutes after injection, respiration very shallow and blood pressure low.	...	44·87	8·125

1 hour after injection tension of CO_2 in femoral artery = 7·42°/o
„ „ „ „ „ vein = 8·58°/o
1 hour 30 minutes „ „ „ artery = 6·65°/o*

* During this last determination artificial respiration was maintained. The lungs were well inflated with warmed air 15 times per minute.

In this experiment the aërotonometer tubes contained air at the commencement.

With the exception of Experiment I. the absolute quantity of CO_2 contained in the venous blood was not decreased. On the contrary, the amount of CO_2 was, in those cases where the animal was severely affected by the venom injections, considerably in excess of that found previously. Under the same circumstances the tension of CO_2 was very much higher than has been found for normal venous blood. In most of the experiments the numbers representing both the absolute amount and the tension of this gas rose together as the condition of the animal became worse and worse. After peptone injections, whilst the tension of CO_2 rose,

the absolute amount of the gas contained in the blood was on the contrary, decreased. I therefore conclude that although the capacity of the blood to carry CO_2 may be, as one might expect from the analogy to other blood-corpuscle-destroyers, somewhat diminished, this is not a prominent feature of poisoning by the venom, and is entirely masked by the operation of other and more potent factors. The gradual increase in both the tension and amount of CO_2 in the venous and also in the arterial blood of the poisoned animal is to a large extent accounted for by the enfeeblement of the circulation and respiratory movements. Before this occurs it is not manifested, but afterwards it progresses hand in hand with the circulatory and respiratory depression. The exudation and hæmorrhage into the lungs which is almost an invariable sequel to the injection of the poison, and whereby considerable areas are for the time being rendered useless, does no doubt also contribute in some degree to the same end. The existence of this factor is indicated in Experiment V., in which artificial respiration was ineffectual in reducing the high tension of CO_2 in the blood of the femoral *artery* to any great extent, and it is interesting to note that examination of the chest of this dog immediately after the experiment, discovered very extensive œdema and hæmorrhages throughout the greater part of the lungs. This pathological condition had evidently so curtailed the available respiratory surface, that the larger portion of the blood passed through the lungs without an opportunity of coming in contact with the air in the alveoli. So that although the alveolar air was maintained of a high degree of purity by artificial inflation, the blood was not enabled to rid itself of its contained CO_2.

(f)—Influence of the venom on the germicidal action of serum.

Weir Mitchell has drawn attention to the fact that the bodies of animals dead from rattle-snake poisoning putrefy with extreme rapidity, and that during life the local extravasations which are characteristic of this class of snake poisoning, as a general rule suppurate, or become gangrenous. Feoktistow[2] also made the

[1] *Loc. cit.* [2] *Loc. cit.*

interesting observation that the bloody effusions in the pleural and pericardial sacs sometimes contained organisms *immediately* after death, and that cultures of these organisms when injected into healthy animals produced no effect. Last year Dr. Ewing[1] repeated some of Nuttall and Buchner's observations on the germicidal power of serum, and instituted a series of comparative experiments with the serum of animals poisoned with *Crotalus* venom. Ewing found that the normal germicidal power of serum was entirely lost after poisoning with *Crotalus* venom.

To ascertain whether the same loss of germicidal power was occasioned by *Pseudechis* venom, the following experiments were made :—A healthy dog, weight 10 Kilos., was injected under the skin of the back with ·0065 gramme of venom, dissolved in 2 cc. of weak salt solution, at 11·30 a.m. At 3 p.m. he was etherised and blood taken from the femoral artery. In the mean time he had vomited considerably, and at 2·45 p.m. he was very sleepy and weak, although he could still walk. The blood was drawn into a sterilised jar under conditions of the strictest asepticism.

At the same time the blood of another dog was drawn under exactly similar conditions, except that this animal had not received a venom injection. Both samples of blood were placed in an ice-chest for forty hours. The venom sample clotted feebly after some hours, and the exuded serum was stained with hæmoglobin. Microscopic examination of both kinds of serum discovered no contamination with any micro-organisms. 5 cc. of each kind of serum were then placed in two sterilised test-tubes.

The test organism employed to determine the relative germicidal powers of the two serums was a twenty-four hours' growth of a broth culture of *Bacillus anthracis*. This was a pure culture of the organism and contained no spores. Each test-tube was inoculated with a platinum wire loopful of the culture and well shaken up. The serum tubes containing the organisms were kept at the laboratory temperature 24 – 25° C. The effect produced

[1] "Med. Record," May 26, 1894.

upon the organism by sojourn in the serums, was ascertained from time to time by withdrawing a wire loopful and mixing this with 10 cc. of nutrient gelatine and making a plate cultivation of the mixture. An indication of the extent to which the growth of the bacilli had progressed in the serum tubes was obtained by counting the number of colonies appearing in the plate cultivations after definite intervals.

The following notes represent some few of the results of these experiments in tabular form, and clearly show that whereas the growth of the organism was as usual hindered by the normal serum, on the other hand the serum from the poisoned animal formed an excellent culture medium. In this particular case the damaging influence of the normal serum was less than is usually the case.

The tables represent the number of colonies of the organism which developed in the plate cultures after various intervals of time.[1]

I.—After Five Minutes Sojourn in Serum.

	Number of Colonies after		
	18 hours.	21 hours.	43 hours.
Normal serum ...	22	109	123
Venom serum ...	39	464	560

II.—After One Hour's Sojourn in Serum.

	Number of Colonies after		
	17 hours.	20 hours.	42 hours.
Normal serum ...	12	672	912
Venom serum ...	987	2000	countless

III.—After Two Hours' Sojourn in Serum.

	Number of Colonies after		
	16 hours.	19 hours.	41 hours.
Normal serum ...	5	560	976
Venom serum	1450	2416	countless

[1] For the performances of greater portion of the troublesome details of these experiments I am indebted to my friends Dr. F. Tidswell and Mr. R. Grant.

IV.—After Three Hours' Sojourn in Serum.

	Number of Colonies after		
	15 hours.	18 hours.	40 hours.
Normal serum ..	19	—	countless
Venom serum ...	2420	4244	countless

Other agents which cause destruction among the blood corpuscles would appear to produce a similar result. Gottstein[1] found that the injection of pyrogallol and acetyl-phenyl-hydrazin into the circulation of animals naturally immune against definite micro-organisms rendered them susceptible to invasion. Under the same circumstances pathogenic germs which locally affect the organism are capable of spreading throughout the whole body.

Action of Venom on the Blood Vessels.

The situation in which the poison is injected is always the seat of some œdema. On cutting into the œdematous tissues, a serous fluid, more or less stained with hæmoglobin, escapes. This in itself is an indication of some alteration in the walls of the blood vessels in the vicinity of the injection, by which the normal transudation processes are affected. Rattle-snake venom produces changes which are of a similar nature, but in which the degree of damage to the endothelial lining of the vessels is much greater. That this venom was capable of playing considerable havoc with the cells lining the blood vessels, was demonstrated by Weir Mitchell and Reichert.[2] These authors moistened the mesentery of animals with *Crotalus* venom and observed under the microscope the rapid formation of extensive capillary hæmorrhages. In a few minutes the whole mesentery became by the coalescence of the numerous hæmorrhagic foci absolutely infiltrated with blood.

I have repeated these experiments, using *Pseudechis* venom, and although the action of this poison is less rapid than was the case in Mitchell and Reichert's experiments the results were identical. The mesenteries of cats and dogs were arranged under the microscope so as to obtain a good view of the circulation in

1 "Deutsche Med. Woch., 1890, 24.

2 *Loc. cit.*

the capillaries. A minute fragment of the poison was then placed near to that portion of the mesentery in the field of the microscope. In a few moments without any previous clouding of the field, or stasis, small hæmorrhages appeared. These invariably occurred first in those positions where the hydrostatic pressure was greatest, viz., from the wall of the capillary near to its origin from an arteriole, and where these capillaries branched or joined one another at right angles. These tiny hæmorrhages increased in number and extent until the whole field was one mass of corpuscles. These appearances are very characteristic and altogether distinct from the escape of corpuscles in diapedesis, and I think there is no doubt that the venom first damages the capillary wall, and that the pressure within causes an actual solution of continuity, the blood escaping through this rupture.

One of the prominent symptoms in animals, after the intravenous injection of a small dose of venom (*i.e.*, so small that the animal may live a sufficiently long time, for the full development of the symptoms), is the occurrence of extensive hæmorrhages. I have often seen more than half the substance of the lungs solid from hæmorrhage into the alveoli and inter-alveolar tissue. If such an affected lung have its blood vessel washed out with saline solution immediately after removal from the body and be then injected with some colouring matter such as indigo-carmine, the fluid injected will not enter the hæmorrhagic portions of the organ to any extent, so that it is probable that thrombosis in the small branches of the pulmonary artery plays some part in these lung hæmorrhages. Silbermann[1] has described an analogous condition in the lungs after intravenous injection of various corpuscle destroying agents. Ragotzi,[2] using the same method as Silbermann, found small thrombosed areas in the lungs of animals poisoned by cobra venom.

Hæmorrhages of greater or less extent are nearly always to be found in the kidneys, liver, and the walls of the alimentary canal,

[1] Ueber das Auftreten multipler intravitaler Blutgerinnungen nach Arsen, Phosphor, und einige Blutgifte.—"Virch. Arch." Bd. 117, 1889.
[2] *Loc. cit.*

and the intima of the aorta and large blood vessels. There is also another situation where a small hæmorrhage is almost invariably found, viz.: under the endocardium of the left ventricle. Feoktistow[1] mentions the constant occurrence of a hæmorrhage in this situation in his experiments with viperine venom.

The full development of all these hæmorrhagic phenomena requires some hours. When venom is intravenously injected, the immediate great fall in blood pressure prevents for the time being the damaged condition of the vascular walls being demonstrated. Subsequently, the escape of blood takes place more and more as the pressure gradually rises after the initial fall.

All kinds of snake venoms which have hitherto been examined, have been shown to contain in varying amount amongst their albuminous constituents a proteid or proteids coagulable by heat. It is of considerable interest that the viperine poisons which contain coaguable proteids in largest amount, exercise this destructive action on blood corpuscles and the walls of blood vessels, to the greatest extent, whereas cobra venom, which contains less than 2 % of coagulable proteid, only exerts such action to a comparatively slight extent. Boiling, or indeed raising the temperature of the solution to 80 – 85° C. deprives venoms of much of their action in this direction, and at the same time largely does away with the capacity of *Pseudechis* poison to produce intravascular clotting. The power of this venom to both destroy blood cells and occasion thrombosis is however not entirely lost, for by increasing the dose of heated venom to at least five hundred times that of the unheated poison which is required to produce instant death by thrombosis, the same result is attained. The whole toxic power of the venom is not however attenuated to this extent. By a large series of experiments on rabbits I found that the minimal dose of *Pseudechis* poison which when subcutaneously injected was sure to occasion a fatal issue, was ·0005 gramme of venom per kilogramme of rabbit. When the solution of the venom was

[1] *Loc. cit.*

previously heated to 85° C. for five minutes, the corresponding amount required to kill was ·0030 gramme.

These observations show that either

(1) Heating to 85° destroys the component of venom which possesses the power of destroying corpuscles to the greatest degree,—or

(2) Heating attenuates the toxic properties of venom in this particular direction to a much greater extent than it does its toxic power generally.

Heating to 85° C. does indeed separate one of the proteid constituents which at this temperature is coagulated and rendered inert. It is therefore quite possible that the difference in the action of venom before and after heating to 85° C. may be so explained. We must however bear in mind that the action of heat on solutions of toxic proteids is a twofold one—

(1) By converting some of the proteids into an inert precipitate.

(2) By impairing their toxic power, without influencing their solubilities, or indeed changing them in any way recognisable by chemical tests.

The first method of action is sudden. When the solution is raised to a definite temperature, some portion of the proteid constituents is coagulated. The second is gradual, and the extent of attenuation depends on the duration of the heating, and the temperature and dilution of the solution.

In the case of *Crotalus* venom Mitchell and Reichert have shown that the coagulable proteids are the constituents which produce a destructive effect on the blood cells and vessel walls to the greatest extent, but I have not yet determined for *Pseudechis* poison to what extent the difference in physiological action between venom previously heated to 85° C. and unheated venom is to be attributed to precipitation of one of the constituents or to gradual attenuation of its power in a particular direction.

IV.—Effect of Venom on the Circulatory Mechanism.

The poisons of all snakes with which experiments have hitherto been made, depress the circulatory mechanism. Different venoms however exercise this action in different degrees, so that whereas interference with the circulatory apparatus plays a very important rôle in the general phenomena of poisoning by some species of snake, with others such interference is, compared with its action in other directions relatively unimportant.

In experiments with the frog's excised heart, when the organ is fed with a solution containing defibrinated blood, by means of a Ludwig and Coat's apparatus, the introduction of all kinds of venom into the feeding mixture, soon brings the contraction to a standstill. If this has once happened, the further substitution of fresh defibrinated blood for the venom-containing solution does not effect a recovery.

By direct observation of the heart in the opened thorax of mammals, in which artificial respiration was maintained, Feoktistow[1] observed great diminution in the cardiac contractions, after the introduction of the venoms of *Crotalus* and *Vipera berus*. When these poisons were intravenously introduced, the contractions of the heart were at first diminished, and afterwards increased in number, becoming at the same time weaker and weaker until death occurred.

The best indication we possess of the efficiency of the circulation is the arterial blood pressure curve. A variation in any of the factors concerned in the general circulation will sooner or later be manifested in this curve. It possesses the additional advantage that it lends itself in an admirable manner to the method of graphic record. A tracing of the pressure of an artery may be allowed to run for hours, and at the end of the time we are in possession of a record of every change of pressure which has occurred. Of course the chart has to be interpreted, and into that interpretation errors may creep, but by simultaneous observations

[1] *Loc. cit.*

of the volumes of abdominal organs such as the kidney and spleen, and by judicious variation of the conditions of the experiment, by means of which the operation of a particular factor can be eliminated, one is generally able to ascertain to which of the factors concerned in the maintenance of the blood pressure the change is to be ascribed.

The effect of several kinds of snake venom upon the blood pressure in the higher animals has been investigated. Brunton and Fayrer,[1] and Ragotzi,[2] worked with cobra poison. Mitchell, and Reichert[3] made a large series of experiments with the venoms of species of *Crotalus* and *Ancistrodon*, *Daboia russellii*, and also cobra. Feoktistow's[4] observations were made with the poisons of *Crotalus* and *Vipera berus*.

Weir Mitchell and Reichert confirmed those results which had already been obtained by Brunton and Fayrer, with cobra poison; and the more recent work of Feoktistow and Ragotzi entirely supports the older observations as regards the main characteristics of the blood pressure curve after poisoning with either rattlesnake or cobra venoms. The work of Weir Mitchell and Reichert is the most important as they pursued their investigations with the venoms of a very large number of different species of snakes, thereby giving us the opportunity of comparing the action, in this respect, of a variety of poisons. The results of these observers possess the additional advantage of having been obtained from an admirably varied and extensive series of experiments.

They found that when the venoms of all these species of serpents were intravenously introduced, there was a distinct lowering of the blood pressure. It fell immediately after the injection, and indeed sometimes before this was completed; and the fall was generally so marked as to indicate a most profound action of the poison upon some part or parts of the circulatory apparatus. If the dose were not immediately fatal, the pressure gradually rose, but finally underwent a more or less steady decline until death. At

[1] *Loc. cit.* [2] *Loc. cit.* [3] *Loc. cit.* [4] *Loc. cit.*

other times the pressure sank without subsequent rise until death ensued. With subcutaneous injection of the venom, the primary sudden fall was in most cases absent.

The tendency in cobra poisoning was to a decided rise of pressure, following the primary fall. In five out of six experiments with the venom, the primary fall was followed by a rise which went above the normal during the asphyxial condition preceding death. After section of the pneumogastrics, they found that the same alterations occurred in the blood pressure as those observed in animals in which these nerves were intact.

When the cord was severed in the cervical region, the primary fall of pressure was not so marked, but the subsequent slow, yet deadly fall occurred. In experiments with cobra poison, on the contrary, even under these conditions, a rise in blood pressure usually preceded death.

Feoktistow found that when a very large dose of the venom of *Crotalus*, or *Vipera berus* was subcutaneously administered, the blood pressure fell as suddenly as when the poison was intravenously introduced. After the pressure had been greatly lowered by the poison, he was unable to produce any effect by stimulating the peripheral ends of the splanchnic nerves, from which he concluded that the peripheral ends of these nerves were paralysed. This he considered was the explanation of the "collosale" sinking of the blood pressure.

Brunton and Fayrer found that the intravenous injection of cobra poison occasioned a sudden temporary drop in the arterial blood pressure, which, under most circumstances speedily regained the previous height. Sometimes, however, this fall was not recovered from, and the animal died in less than sixty seconds from the time of the injection, *but the arterial blood pressure remained considerably above zero.* This was considered noteworthy by these authors, and they thought it showed "that the arteries or capillaries must have been much contracted, thus opposing a barrier to the exit of blood from the arteries into the veins."

In a previous section I have mentioned a similar occurrence in many of my experiments with the intravenous injection of *Pseudechis* venom. At first this maintenance of a considerable pressure in the arteries after the sudden death of the animal puzzled me greatly. There could be however only one explanation of the phenomenon, viz.: that the blood *could not* empty itself as usual into the veins. In my experiments the reason was that the arterial system was blocked by the occurrence of intravascular clotting, and it is quite possible that this was also the explanation in Brunton and Fayrer's experiments.

In the experiments made by these observers death usually occurred from asphyxia, during which the blood pressure curve exhibited the same rise of pressure above the normal as obtains when an unpoisoned animal is asphyxiated.

Speaking of this maintenance of circulatory efficiency, Brunton and Fayrer say,—"The long continuance of the cardiac pulsations after apparent death excludes failure of the circulation as the usual cause of death; and we are thus brought, by exclusion, to regard death caused by the bite of the cobra, or by its poison introduced into the body in any other way, as death from asphyxia. The truth of this view is well illustrated by a series of experiments which show that the vitality of the heart may be retained for a considerable time if the respiration is kept up. It shows also that the convulsions which have been remarked by Russell and all subsequent observers as almost always preceding death are not due so much to the action of the poison itself on the nervous centres, as that they depend on the irritation which is produced in them by the venosity of the blood."

(a)—The effect of Pseudechis venom upon the excised heart of cold-blooded Vertebrates.

I have experimented with the excised hearts of frogs and turtles. In the case of either of these animals a perfusion cannula was inserted in the ventricle and tied. The cannula was connected with a Ludwig and Coat's apparatus, and the record of the heart-

beat taken on a slowly moving cylinder covered with smoked paper. One of the Marriott's tubes of the apparatus was previously filled with a mixture of defibrinated mammalian blood one part, and ·65% sodium chloride solution, containing 1 in 1,000 Na_2CO_3, two parts. The other tube was filled with a similar solution containing a known proportion of venom. The amount of venom contained in the solution was either 0·1 or 1%. The former appeared to at first stimulate the heart, but it speedily began to beat more slowly, then became irregular and feeble, and eventually stopped in diastole after about thirty minutes. The stronger solution of venom produced immediate slowing and enfeeblement of the contractions, which became diminished in rate and extent until in a few minutes the heart ceased to beat.

If the stronger venom-containing solution was allowed to flow through the heart for only ten seconds, the substitution of the unpoisoned feeding mixture failed to produce any recovery of the cardiac contractions.

Two experiments were made with the hearts of small turtles by means of a Ludwig and Coat's apparatus. In the former ·1% of venom was employed, and in the latter a feeding solution containing 1% of the venom was allowed to flow through the heart for one hundred seconds, and then replaced by the blood solution only. This had however, no effect, and the beats became rapidly less and less apparent until they were imperceptible in twelve minutes from the introduction of the venom.

(*b*)—*Effect on Mammals.*

I commenced my investigations into the action of the venom on the circulatory apparatus, by taking tracings of the pressure in an artery, both during and after the introduction of the poison. The venom was introduced by injection subcutaneously, into the peritoneal cavity, or directly into the circulation through a vein or artery. I chose intravenous injection to begin with, because the method of subcutaneous inoculation introduces an unknown quantity—viz., rate of absorption. This method has however,

the disadvantage that the injection of even very small quantities of the venom directly into the circulation occasions so great an increase in the coagulability of the blood, that this fluid frequently clots in the vessels. When this occurs at all extensively the circulation is speedily terminated and death ensues. It is indeed very difficult to prevent intravascular clotting, and before we can draw conclusions as to the action of the venom upon the heart or other portion of the vascular mechanism we must be sure that thrombosis has not occurred.[1] In my earlier experiments I was not aware of this action of venom upon blood plasma, and the inconsistent results I obtained puzzled me greatly. The whole matter was however cleared up when I discovered that the extraordinary lack of uniformity in, and frequent sudden termination of my experiments, was due to the arrest of the circulation by solidification of the blood.

The animals used were dogs and rabbits. The results were substantially the same with both animals. The effect of the poison on the blood pressure was investigated under a variety of experimental conditions with and without curari. In some experiments the vagi were previously severed, in others not. Two experiments were made on animals in which the cord had been divided at the level of the third cervical vertebra. In five cases a simultaneous record of the volume of either the kidney or the spleen was obtained, and in nearly every case the condition of the respiration was recorded at the same time by connecting the trachea with a Marey's tambour and writing lever. The records were taken on a Hering's kymograph. In those experiments which lasted many hours a continuous record was not taken, but the kymographion was stopped, and set going again for a few minutes at intervals of fifteen or thirty minutes, or less as occasion demanded.

The general features of the blood pressure record following the intravenous injection of *Pseudechis* venom are the same as those

[1] Many of the results of previous experimenters with snake poisons are vitiated by their ignorance of this possibility.

observed by Weir Mitchell and Reichert, and Feoktistow, to follow the introduction of the venom of *Crotalus*, *Ancistrodon*, *Daboia russellii*, and *Vipera berus* into the circulation. Directly the venom reaches the heart there is a sudden great fall of the arterial blood pressure. This fall is accompanied by diminution in the extent of the accession of pressure due to each beat of the heart, and is the more marked the greater the rapidity with which the solution of venom is introduced, and the nearer the vein chosen for its introduction is to the heart. The extent of this fall is dependent on the degree of concentration with which the poison reaches the heart. When its dilution with blood is accomplished, by introducing it into a vein far removed from the heart, its effect is lessened, and if the injection be carried out sufficiently slowly, this steep descent is absent, and the pressure declines slowly and steadily until death.

Also when the venom is injected into the carotid or vertebral artery, so that it is carried away from the heart and well diluted with blood before it is returned to this organ, the effect is diminished, notwithstanding the fact that under these circumstances the poison reaches the nervous system in the greatest concentration. If the fall in pressure is to be ascribed (as Mitchell and Reichert concluded was the case in their experiments) to the sudden relaxation of the arterioles in the abdominal area, by paralysis of the vaso-motor centre in the medulla, one would expect to obtain the most marked result when the poison was enabled to operate upon the medulla in greatest concentration, and not the reverse result, as I have always obtained.

The initial fall of pressure may be only temporary, and in the course of a few minutes to one hour may rise again to nearly the normal, as is shown in the majority of the experiments.

This recovery, when it occurs, does not however last long if a fatal dose has been injected. After remaining as high, or nearly as high as before the injection, for a period varying from a few minutes to some hours, according to the dose which has been

injected, the pressure begins to slowly decline, and continues to do so until it is only equal to a few millimetres of mercury, when the enfeebled circulation is no longer adequate to support life, and the animal dies.

This fatal fall of blood pressure also invariably occurs in those cases where artificial respiration is maintained. Without this assisted respiration the pressure declines more quickly as the cardiac depression is accentuated by a diminished supply of oxygen, **due to simultaneous failure of respiration.**

Up to within a very short interval before death, when the circulation is almost ended, vagus stimulation produces the usual slowing or stoppage of the heart. (*cf.* Exs. 10, 11, and 14.)

The intravenous injection of the poison, however, neutralises that normal retarding influence which is exercised by the vagus, and is so marked in some dogs. In these animals the large slow cardiac contractions are almost immediately superseded by contractions increased in rate, and much diminished in force after the injection of venom. Section of the vagi under these circumstances **is without effect.**

When the venom is subcutaneously injected, the decline of the blood pressure is more gradual, and the primary sudden fall so characteristic of intravenous injection is absent. The time which elapses before the pressure begins to fall depends upon the amount injected and the rapidity of absorption. A small dose (·005 gramme per kilo.) when introduced under the skin, may not materially affect the blood pressure for three hours subsequent to the injection, whereas the same amount introduced into the peritoneal cavity may cause a marked fall in pressure during the first fifteen minutes. Larger doses however act much more rapidly, and if a sufficient quantity is injected the blood pressure often falls to one half of its previous height in three or four minutes **after the introduction of the poison.**

(c)—*Explanation of the fall in blood pressure.*

Weir Mitchell and Reichert, who observed the same diphasic character in the blood pressure curve after intravenous injection of various kinds of snake poison, were of opinion that the primary fall was chiefly due to the depressant action of the venom upon the vaso-motor centres in the medulla oblongata, and slightly upon the heart, but that the ultimate fall of pressure was cardiac in origin.

From the results of experiments the details of which are given at the end of this section of the present paper, I have come to the conclusion that in both cases the fall in pressure is mainly due to a direct action of the poison upon the heart. The most important evidence which has led me to this conclusion is drawn

(1) From observations on the blood pressure in experiments in which the cervical cord had been previously divided, and

(2) From those experiments in which observation of the volume of the spleen or kidney were made at the same time as a record of the arterial blood pressure.

In experiments 16 and 17, the intravenous injection of ·0005 and ·0008 gramme of venom into two dogs with severed cervical cord, produced precisely similar results to those which I have frequently obtained with normal dogs. The only difference was that in the experiments in which the cord had been previously divided the blood pressure was reduced to almost one half its original height before the introduction of the venom. In experiment 16 the larger dose killed the animal in ten minutes, and the pressure fell steadily until death, whereas in experiment 17, in which the dose was smaller, the animal lived for nearly two hours, and the blood-pressure record exhibited the same temporary recovery as had been observed in the majority of the experiments with moderate doses of the poison. Were the numbers tabulated in these two experiments multiplied by two, they would correspond exactly with those of experiments in which the cord was intact.

Experiments 30, 31, 32, and 33, in which a simultaneous record of the arterial blood pressure and the volume of the kidney or

spleen was obtained, show that both curves decline and rise together. The fall in pressure is accompanied by a simultaneous and equally abrupt diminution in the volume of the spleen and kidney, and in those experiments in which the arterial pressure recovered, the volume of these organs increased at the same time, and again diminished as the pressure in the arteries finally fell. Had vascular dilatation (provided it affected these organs), been the explanation of the fall in pressure, the two curves would have crossed one another and not run in a parallel direction.

I think these organs, and especially the spleen, may be taken as fair samples of the area in which vascular dilatation due to vaso-motor paresis would occur, and this evidence, taken in conjunction with the results of the experiments on animals with divided spinal cords, justifies the conclusion that the fall in blood pressure is cardiac in origin, and that any result of vaso-motor paralysis is insignificant in comparison with the direct weakening of the cardiac contractions. Such a direct effect upon the heart would not be unexpected, for, as I have mentioned, all venoms act as cardiac poisons when supplied to the excised heart of cold blooded vertebrates.

Diminished peripheral resistance, owing to vaso-motor paresis, does no doubt contribute a share to this final fall in pressure, but that vaso-motor action is not altogether in abeyance, and may still be called into operation by sufficient stimulus is shown by the effect of asphyxiation on a curarised animal in which the pressure has sunk to less than one-half its previous height. In experiments 14 and 15, the pressure was in both instances, under such circumstances, doubled by suspension of the artificial respiration. In other experiments upon rabbits, as soon as the respiration showed signs of incipient failure, artificial inflation was employed. Directly this was discontinued, and the animal had to depend on its own inadequate respiratory movements for a supply of oxygen the pressure rose at once. The only cause of such a rise is that brought about by the vaso-motor mechanism. This is still capable of about doubling the arterial pressure for

the time being, even within a few minutes of the death of an animal.

Far from considering interference with the vaso-motor centre important, in the phenomena of poisoning by this venom, I think that the manner in which this centre, and also the vagus centre escapes, when, as I shall presently show, the activity of a closely situated group of cells, the respiratory centre is absolutely in abeyance, is one of the most remarkable instances of the selective operation of a poison, with which I am acquainted.

Ragotzi[1] has pointed out that the vaso-motor and vagus centres enjoy the same comparative immunity from the action of cobra poison.

That the enormous fall in blood pressure is not due to paralysis of any peripheral termination of the splanchic nerves as Feoktistow[2] believed was the explanation of the corresponding fall in his experiments with *Crotalus* poison, is shown by Experiment 5, in which stimulation of the peripheral ends of these nerves, produced in the late stages of poisoning, as great a rise of pressure *proportionately* as under normal circumstances. Feoktistow does not give a detailed account of the experiments from which he drew his conclusions, but it is not improbable that he had occasioned extensive thrombosis in the portal area by his intravenous injection, which would be an excellent reason why any further peripheral resistance in the same area, should not be manifest in the blood pressure curve.

There is a further interesting point shown by the blood pressure record, in those experiments in which I have given at intervals two or three injections of venom intravenously. The injection of a very small quantity of venom (·00005 gramme per kilo.) produces a very considerable and immediate fall of blood pressure, which is, however, recovered from. If, after the lapse of one hour when the pressure has regained, or almost regained its former

---

1 Virchow's Archiv., Bd. CXXII., S. 232.

2 *Loc. cit.*

height, a further injection, containing ten or twenty times the former quantity be made, this causes a second drop in the blood pressure. The fall is, however, in no way so great as in the first instance, notwithstanding the fact that the quantity injected is so much larger, and whereas the recovery from the cardiac depression due to the first dose, was not complete until from forty minutes to one hour, the pressure regains the normal, or about the normal, in fifteen minutes after the second injection. If, after this second recovery, a third dose of the poison, of the same quantity as the second injection (or even double that quantity) be introduced, it has little or no effect upon the blood pressure. The only explanations of such results are either that the cardiac muscle has become much less sensitive to the operation of the poison, or that in the meantime, some body possessed of properties which interfere with the operation of the poison, has become present in the blood plasma. This point, however, opens up the whole problem of immunity and the protective reaction of the organism against the poison, which I hope to discuss at some future time.

Precisely the same result was observed by Wooldridge when nucleo-albumens were repeatedly injected, and the enormous fall in blood pressure produced by injecting albumoses into a vein, does not occur if a second injection be made after the animal has recovered from the first.

Protocols of Experiments showing the influence of the Venom upon the Arterial Blood Pressure.

These experiments were performed on dogs and rabbits. The poison was introduced either intravenously, subcutaneously, or into the peritoneal cavity. Most of the experiments in which the poison was injected into a vein were made upon dogs, whereas in those cases where subcutaneous injection was employed, rabbits were used. Graphic records of the blood pressure were taken upon a Hering's kymograph by means of a mercury manometer. The time and duration of the injection was indicated by raising the signal line. Underneath the signal line a time marker connected with a seconds clock gave the value of the abscissa. In

those experiments which lasted some hours, a continuous record was not taken, but the kymograph was stopped and set going again for a few minutes, at intervals of fifteen or thirty minutes or less as occasion demanded. In tabulating the curves, the height of the pressure tracing at any particular moment above the abcissa was measured in mm. and this number doubled. In every case the mean pressure between the limits of the respiratory and cardiac undulations was taken.

(1) *Experiments with dogs in which the vagi had been previously severed.*

Experiment 1—Dog, weight 4·1 kilogrammes, ·065 gramme of morphia injected hypodermically; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			144	injection of ·0002 gramme per kilo. of body weight into the external jugular vein. Injection lasted 5 minutes.
0	5	30	122	
0	10	0	104	
0	15	0	72	
0	30	0	82	
0	45	0	118	
1	0	0	98	
1	15	0	78	
1	30	0	65	
1	45	0	37	
2	0	0	30	
2	20	0	34	
2	40	0	15	
3	0	0	13	
3	20	0	13	dead

Experiment 2—Dog, weight 3·4 kilos., ·065 gramme morphia hypodermically; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			124	injection of ·001 gramme per kilo. of body weight into jugular vein. Injection lasted 3½ minutes.
0	3	30	48	
0	5	0	34	
0	8	0	44	dyspnœic struggles
0	10	0	14	
0	11	0	10	dead

Post mortem examination revealed clots in the vena cava inferior and portal vein.

Experiment 3—Dog, weight 5·4 kilos. ·065 gramme of morphia hypodermically ; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			108	·00005 gramme per kilo. of body weight injected into jugular vein. Injection lasted ½ minute.
0	1	0	90	
0	2	0	66	
0	3	0	54	
0	4	0	55	
0	5	0	64	
0	6	0	72	
0	7	0	78	
0	8	0	83	
0	9	0	90	
0	10	0	94	
0	15	0	114	
0	20	0	122	
0	25	0	124	
0	30	0	116	
0	35	0	113	
0	40	0	112	
1	0	0	102	bled to death.

Experiment 4—Dog, weight 5·5 kilos., ·065 gramme of morphia hypodermically ; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			180	·0005 gramme per kilo. injected in external jugular vein. Injection lasted 50 seconds
0	1	0	118	
0	2	0	94	
0	5	0	90	
0	10	0	112	
0	15	0	178	
0	30	0	172	
0	45	0	156	
1	0	0	114	
1	15	0	80	
1	30	0	81	
1	45	0	64	respiration greatly diminished in extent
2	0	0	30	
2	10	0	14	dead. Respiratory gasps after cessation of circulation.

Experiment 5—Dog, weight 3·2 kilos., ·075 gramme of morphia hypodermically ; ether during operation.

When the pressure had been reduced from 136 to 38 mm., stimulation of the left splanchnic at its entrance into the abdomen by a faradaic current caused the pressure to rise to 61 mm.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			136	·0004 grammes per kilo. of body weight injected into right carotid artery. Injection lasted 30 seconds.
0	0	30	120	
0	1	0	96	
0	5	0	85	
0	15	0	64	heart beat very small
0	30	0	72	heart beat improved
0	45	0	100	heart beat improved
1	0	0	108	respiration much slower
1	10	0	63	respiration very slow
1	15	0	48	respiration very slow
1	30	0	38	left abdominal splanchnic stimulated
1	30	10	61	
1	31	0	40	
1	45	0	31	
2	0	0	26	
2	30	0	18	
2	40	0	14	dead

Experiment 6—Dog, weight 4 kilos., ·065 gramme of morphia hypodermically ; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			142	·0003 grammes per kilo. of body weight injected in external jugular vein. Injection lasted 6½ minutes.
0	7	0	68	respiration slow and slight
0	10	0	42	respiration slow and slight
0	15	0	39	respiration very slow and slight
0	20	0	46	respiration very slow and slight
0	30	0	49	10 cc. 1% solution of $CaCl_2$ injected into jugular vein, caused immediate thrombosis of the whole vascular system.

This experiment was terminated after thirty minutes by injecting a solution of $CaCl_2$ which occasioned extensive intravascular clotting.

Experiment 7—Dog, weight 7·7 kilos., ·1 gramme morphia hypodermically ; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	204	·0006 gramme per kilo. injected into jugular vein. Injection lasted 1½ minutes.
0 2 0	105	respiration increased
0 3 0	139	,, ,,
0 10 0	181	,, ,,
0 35 0	194	respiration slower than normal
1 0 0	160	respiration inspiratory in charactor
1 30 0	126	diminished respiration inspiratory in character
1 45 0	108	,, ,, ,, ,,
2 0 0	103	,, ,, ,, ,,
2 15 0	97	respiration nearly ceased
2 16 0	95	asphyxial convulsions during which pressure rose to 143
2 17 0	135	
2 18 0	21	dead

In this experiment the respiration was affected to a much greater extent than is usual with dogs under the experimental conditions, and the animal died of asphyxia. During the asphyxia the pressure rose considerably.

Experiment 8—Dog, weight 15 kilos., ·15 gramme morphia hypodermically ; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	186	·00005 gramme per kilo. injected into jugular vein.
0 2 0	127	
0 3 0	114	
0 4 0	99	
0 5 0	89	
0 10 0	92	
0 15 0	105	
0 30 0	127	
0 45 0	158	
1 0 0	164	·0005 gramme per kilo. injected
1 2 0	101	
1 5 0	83	
1 10 0	130	
1 20 0	159	
1 30 0	162	
2 0 0	156	·0005 gramme per kilo. injected
2 1 0	142	
2 5 0	140	
2 10 0	148	
2 15 0	148	
2 30 0	151	
3 0 0	153	bled to death

(2) *Experiments on dogs with vagi intact.*

Experiment 9—Dog, weight 9½ kilos., ·1 gramme morphia hypodermically ; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm.	Excursion of the stile at each heart beat in mm.	Remarks.
Normal	95	21·0	·00001 gramme per kilo. injected into jugular vein; injection lasted 2½ minutes.
0 2 30	64	1·0	
0 5 0	52	·8	
0 10 0	65	1·0	right and left vagi cut; no effect
0 10 30	65	1·0	

The restraining effect of the vagus on the heart beat was very marked in this dog. It disappeared in one minute after the injection of the poison, and when the vagi were severed this was followed by no alteration in heart beat or blood pressure.

Experiment 10—Dog, weight 4 kilos., ·065 gramme morphia hypodermically; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm.	Excursion of the stile at each heart beat in mm.	Remarks.
Normal	152	8·0	·0008 grammes per kilo. of body weight injected into jugular vein. Injection lasted 10 minutes.
0 10 0	90	2·0	
0 12 0	94	2·0	right and left vagi cut. No effect.
0 13 0	94	2·0	peripheral end of right vagus stimulated, pressure fell to 30 mm.
0 22 0	116	2·5	
0 45 0	76	2·0	
1 0 0	40	·7	
1 15 0	41	·7	
1 30 0	32	·4	
1 53 0	18	less	
1 56 0	14	less	dead

Shortly after introduction of the poison the vagus beats disappeared. Subsequent section of vagi produced no effect. Stimulation of peripheral end of right vagus stopped the heart.

Experiment 11—Dog, weight 13·5 kilos., ·15 gramme morphia hypodermically; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm.	Excursion of the style at each heart beat in mm.	Remarks.
Normal	92	9·0	·00003 gramme per kilo. injected into jugular vein.
0 2 0	58	1·5	
0 5 0	46	1·0	
0 20 0	68	·75	trachea clamped.
0 22 0	170		
0 25 0	85	·5	
0 45 0	74	·5	right and left vagus cut.
0 46 0	75	·5	
0 50 0	70	·5	peripheral end of right vagus stimulated caused pressure to fall to 26 mm.
1 0 0	74	·7	·00045 gramme per kilo. injected
1 2 0	54	·5	
1 5 0	40	·4	
1 20 0	68	·5	
1 40 0	71	·5	
2 0 0	80	·5	·0005 gramme per kilo. injected
2 1 0	56	·5	
2 2 0	36	·4	
2 20 0	67	·5	
2 40 0	69	·5	
3 0 0	65	·5	
3 30 0	42	·4	
4 0 0	34	·3	
4 30 0	31	nearly imperceptible	
5 0 0	19		
5 10 0	13		dead

Vagus beats disappeared in two minutes after the injection of the venom. Twenty minutes after injection of poison pressure equalled 68 mm., and clamping trachea raised it to 170 mm. Severing both vagi produced no effect. Stimulation of peripheral end of right vagus stopped the heart.

Experiment 12—Dog, weight 15·8 kilos., ·15 gramme morphia hypodermically; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm..	Excursion of the style at each heart beat in mm.	Remarks.
Normal			110	28	·00003 grammes per kilo. injected into jugular vein. Injection lasted 1 minute.
0	0	30	146	32	
0	1	0	96	22	
0	2	0	83	7	
0	3	0	74	3	
0	4	0	66	1	
0	5	0	60	1	
0	10	0	48	·25	
0	15	0	59	·75	
0	30	0	84	1	
0	40	0	114	2	
0	49	0	113	2	·0005 gramme per kilo. injected
0	50	0	114	1·5	
0	51	0	76	1	
0	52	0	58	1	
0	53	0	64	1	
0	54	0	74	1	
0	55	0	80	1·2	
0	56	0	88	1·5	
1	0	0	108	1·5	
1	7	0	114	1·75	·0005 gramme per kilo. injected
1	7	30	112	1·5	
1	8	0	110	1·5	
1	10	0	105	1·25	
1	15	0	108	1·5	
1	20	0	113	2	bled to death

Experiment 13—Dog, weight 6·8 kilos., ·1 gramme morphia hypodermically; ether during operation. Curare injected into jugular vein.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			150	·001 gramme per kilo. injected into jugular vein. Injection lasted 10 seconds.
0	1	0	90	
0	2	0	40	
0	3	0	70	
0	4	0	92	intravascular clotting occured
0	6	0	85	dead

(3) *Experiments on curarised dogs, with artificial respiration, and vagi severed.*

Experiment 14—Dog, weight 10·2 kilos., ·125 gramme morphia hypodermically; ether during operation. Curare injected into jugular vein.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	150	·000075 gramme per kilo. of body weight injected in jugular vein. Injection lasted 50 seconds.
0 1 0	101	
0 2 0	90	
0 3 0	88	
0 4 0	92	
0 5 0	94	
0 6 0	95	
0 7 0	104	
0 15 0	130	
0 30 0	142	
0 45 0	136	
1 0 0	135	
1 30 0	140	
2 0 0	127	
2 30 0	110	
3 0 0	122	
3 30 0	97	
4 0 0	91	
4 30 0	82	
5 0 0	70	
5 30 0	64	
6 0 0	62	
6 30 0	48	artificial respiration suspended
6 31 0	101	artificial respiration continued
6 32 0	56	
7 0 0	41	peripheral end of right vagus stimulated, pressure fell to 20 m.m.
7 30 0	33	
8 0 0	27	
8 10 0	21	dead

Suspension of artificial respiration for one minute raised the pressure from 48 to 101 mm.

Experiment 15—Dog, weight 15·9 kilo., ·2 gramme morphia hypodermically; ether during operation. Curare injected into jugular vein.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks,
Normal			136	·00005 gramme per kilo. of body weight injected into jugular vein.
0	0	30	100	
0	1	0	78	
0	2	0	62	
0	3	0	56	
0	10	0	40	
0	15	0	64	
0	30	0	103	
1	0	0	128	·0025 gramme per kilo. injected
1	1	0	76	
1	2	0	65	
1	3	0	54	
1	15	0	71	
2	0	0	62	artificial respiration suspended
2	1	0	128	artificial respiration continued
2	2	0	90	
2	5	0	53	
2	30	0	37	
2	40	0	28	
2	43	0	19	dead

Suspension of artificial respiration for one minute raised the pressure from 62 to 131 mm.

(4) *Experiments on dogs after severing the spinal cord in the cervical region.*

Experiment 16—Dog, weight 6·6 kilos., ·1 gramme of morphia given hypodermically; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			101	cord severed at level of 3rd cervical vertebra
0	5	0	50	·00008 gramme per kilo. injected into jugular vein.
0	5	30	42	
0	6	0	36	
0	7	0	30	
0	8	0	29	slight inspiratory gasps.
0	9	0	20	" " "
0	10	0	14	dead

Experiment 17—Dog, weight 7 kilos., ·1 gramme morphia hypodermically; ether during the operation.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	127	
0 2 0	68	cord severed at level of 3.d cervical vertebra. ·00005 gramme per kilo. injected into jugular vein.
0 2 30	54	
0 3 0	47	
0 4 0	41	
0 5 0	34	
0 10 0	40	
0 15 0	45	
0 20 0	48	
0 30 0	56	
0 45 0	57	
1 0 0	44	
1 15 0	38	
1 30 0	33	
1 40 0	26	
1 50 0	22	
1 52 0	13	dead

(5) *Experiments on rabbits, vagi intact; without artificial respiration.*

Experiment 18—Rabbit, weight 1 kilogramme; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	107	·00006 gramme per kilo. of body weight injected into external jugular vein. Injection lasted 30 seconds.
0 0 30	70	
0 1 0	29	intravascular clotting.
0 2 0	27	dead

Experiment 19—Rabbit, weight 1·2 kilogrammes; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	105	·00004 gramme per kilo. injected in jugular vein. Injection lasted 30 seconds.
0 0 30	83	
0 1 0	49	
0 2 0	53	
0 5 0	64	
0 6 0	69	intravascular clotting.
0 7 0	48	dead

Experiment 20—Rabbit, weight 1 kilo.; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			97	·00002 gramme per kilo. injected into jugular vein. Injection lasted 30 seconds.
0	0	30	76	
0	1	0	64	
0	2	0	51	
0	5	0	53	
0	10	0	60	
0	15	0	74	
0	30	0	68	
0	45	0	71	respiration increased in rate and extent.
1	0	0	62	,, ,, ,,
1	15	0	54	,, ,, ,,
1	30	0	45	,, ,, ,,
1	45	0	44	,, ,, ,,
2	0	0	40	respiration diminishing.
2	15	0	33	respiration still greater in both rate and extent than normal.
2	30	0	27	convulsions.
2	38	0	20	dead.

In the next two experiments the amplitude and rate of the respiratory excursions of the tambour-lever is placed opposite the numbers representing the arterial pressure at the time being. From these it will be seen that the fall in blood pressure is not in any way dependent upon diminished respiratory efficiency.

Experiment 21—Rabbit, weight 1·6 kilos.; ether during operation.

Time. hrs.	mins.	secs.	Blood pressure in mm.	Respiration. amplitude in mm.	Respiration. rate per minute.	Remarks.
Normal			126	15	58	·00002 gramme per kilo. of body weight slowly injected into jugular vein.
0	1	0	114	17	72	
0	1	30	106	16	66	
0	15	0	124	52	52	
0	45	0	130	42	84	·00003 gramme per kilo. injected into jugular vein.
1	0	0	84	48	56	
1	15	0	95	51	60	
1	45	0	92	50	60	
2	15	0	65	45	55	
2	30	0	40	40	53	
2	42	0	26	—	—	convulsions.
2	43	0	21	65	12	
2	43	30	16	27	21	
2	44	0	13	—	—	dead.

In this experiment the respiration was well maintained for two hours forty-two minutes, when asphyxial convulsions occurred, due to the feeble circulation.

Experiment 22—Rabbit, weight 1·75 kilos.; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm.	Respiration. amplitude in mm.	Respiration. rate per minute.	Remarks.
Normal	107	13	72	·000005 gramme per kilo. injected into jugular vein.
0 3 0	96	11	60	
0 18 0	84	11	69	
0 48 0	80	10	52	
1 8 0	82	9	44	
1 23 0	72	10	36	
1 38 0	80	11	40	·000015 grm. per kilo. injected.
1 40 0	55	11	45	large slow vagus beats.
1 41 0	23	50	67	convulsions.
1 41 10	58	65	71	
1 41 30	20	12	52	
1 43 0	12	64	2	
1 43 20	11	55	4	
1 43 40	8	—	—	dead.

In this experiment the respiration showed signs of failure, but the asphyxial convulsions must be attributed to the simultaneous enfeeblement of the circulation.

In the next two experiments the venom solution was raised to the temperature of 85° C. for a moment previous to injection.

Experiment 23—Rabbit, weight 1·4 kilos.; ether during operation.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	106	injection of ·0035 gramme per kilo. into external jugular vein.
0 1 0	88	
0 2 0	74	
0 3 0	68	
0 5 0	78	
0 10 0	104	
0 30 0	112	
1 0 0	105	
2 0 0	102	
3 0 0	106	killed by bleeding.

Experiment 24—Rabbit, weight 1·8 kilos.; ether during operation. Venom solution heated to 85° C. previous to injection.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			102	·01 gramme per kilo. injected into jugular vein. Injection lasted 3 minutes.
0	3	0	82	
0	4	0	80	
0	5	0	70	respiration doubled in rate and extent.
0	6	0	44	,, ,, ,,
0	7	0	36	,, ,, ,,
0	8	0	40	respiration diminishing.
0	9	0	33	respiration diminishing but greater than normal.
0	10	0	56	convulsions.
0	11	0	12	long slow gasping respiration.
0	12	0	8	dead.

In this experiment when the pressure had fallen to 33 mm., asphyxial convulsions occurred, although the respiration at the time was above the normal, both in rate and extent.

Observations on the blood pressure after subcutaneous injection of the poison.

When the poison is subcutaneously introduced, the effect upon the blood pressure is complicated by the results of simultaneous paralysis of the respiration, to a much greater extent than under the previous experimental conditions. The cause of this difference will be discussed in the section devoted to the consideration of the effects of the venom on the respiratory mechanism, but it is necessary to mention the fact now. Blood pressure records taken from an animal into which the poison has been subcutaneously injected exhibit the effects of the primary asphyxial stimulation of the vagus and vaso-motor centres, and the final paralysis of both of these, together with the weakening of cardiac contractions owing to diminished oxygenation.

Accordingly, in studying the effect of the poison upon the blood pressure when subcutaneously or intra-peritoneally injected, it is necessary to eliminate these secondary results due to its operation at the same time upon the respiratory mechanism, by means of

artificial inflation of the lungs. The effect upon the blood pressure without artificial respiration can, however, be seen on reference to the experiments at the end of the section on the effects of the venom upon the respiration. In the detailed account of those experiments, the pressure in the carotid artery at intervals during the course of the experiment, is enumerated, together with the rate and amplitude of the respiratory movements. On comparing the experiments with and without artificial respiration, it will be seen that life is only prolonged to a very short extent by maintaining the respiratory efficiency of the animal by mechanical inflation.

If death from asphyxia be prevented by such means, the animal succumbs within a few minutes from heart failure. Experiments 26, 27 and 28, in which the artificial inflation was suspended for a few seconds at intervals in order to ascertain the extent of the action of the poison on the respiratory mechanism, show that the heart ceased to beat within five minutes from the time when natural respiration had completely ceased.

The animals upon which these experiments were performed were rabbits. They were anæsthetised with ether, and the carotid artery connected with a mercury manometer. The trachea was connected with a Marey's tambour and the artificial respiration pump. The air was warmed by being passed through coils of lead pipe immersed in hot water before being pumped into the lungs. The arrangement of these connections was such as to admit of changing from artificial to natural respiration or *vice versa* by turning a tap, and without interfering with the registering tambour. A tracing of the normal blood pressure was first obtained, and then the poison dissolved in 1 cc. of normal salt solution, injected. Further tracings were taken at intervals of fifteen minutes or less, during the course of the experiment. The poison was injected into the peritoneal cavity in two experiments and in the others under the skin of the abdomen. The result of all the

experiments was the same. The pressure fell slowly at first, and rapidly at the end of the experiment. With large doses, Experiments 25, 26, 27, it fell considerably, even during the first ten minutes, but with the smaller quantities it remained nearly at the normal for the first two hours and then fell rapidly until death. At the same time the excursions of the style occasioned by each beat of the heart were very greatly diminished until they became imperceptible.

Experiment 25—Rabbit, weight 1·3 kilos.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	90	·01 gramme of poison per kilo. of body weight injected into peritoneal cavity.
0 10 0	61	
0 25 0	59	
0 35 0	25	
0 40 0	22	
0 55 0	23	
0 57 0	31	
1 5 0	24	
1 15 0	13	dead.

Experiment 26—Rabbit, weight 1·6 kilos.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	94	·0075 gramme per kilo. of body weight injected into peritoneal cavity.
0 10 0	89	
0 15 0	94	
0 30 0	82	
0 45 0	88	
1 0 0	74	
1 10 0	50	artificial respiration suspended for 7 seconds natural respiration slight and inadequate
1 10 10	89	vagus beats.
1 15 0	51	
1 20 0	44	artificial respiration suspended 5 seconds. Natural respiration just perceptible.
1 30 0	28	artificial respiration suspended 5 seconds. Natural respiration absent.
1 32 0	10	dead.

Experiment 27—Rabbit, weight 1·25 kilos.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			91	·0075 gramme per kilo. injected subcutaneously into abdominal wall.
0	8	0	85	
0	10	0	90	
0	15	0	94	
0	30	0	88	
0	45	0	87	
1	0	0	82	
1	15	0	73	artificial respiration suspended during 7 seconds. Natural respiration very feeble.
1	30	0	71	
1	40	0	64	
1	50	0	55	
2	0	0	42	artificial respiration suspended during 7 seconds. Natural respiration absent.
2	5	0	28	
2	10	0	20	
2	13	0	14	dead.

Experiment 28—Rabbit, weight 1·75 kilos.

Time. hrs.	mins.	secs.	Blood pressure in mm. of mercury.	Remarks.
Normal			98	·0035 gramme per kilo. of body weight injected under skin of abdomen.
0	30	0	99	
0	45	0	90	
1	0	0	89	
1	15	0	88	
1	25	0	92	
1	45	0	92	artificial respiration suspended 5 seconds. Natural respiration feeble.
2	0	0	91	
2	15	0	96	
2	30	0	92	
2	45	0	84	artificial respiration suspended 5 seconds. Natural respiration very feeble.
3	0	0	56	artificial respiration suspended 5 seconds. Natural respiration just perceptible.
3	15	0	22	artificial respiration suspended 5 seconds. Natural respiration absent.
3	16	0	6	dead.

Experiment 29—Rabbit, weight 1·2 kilos.

Time. hrs. mins. secs.	Blood pressure in mm. of mercury.	Remarks.
Normal	102	·0035 gramme per kilo. of body weight injected under skin of abdomen.
0 15 0	100	
0 30 0	97	
0 45 0	97	
1 0 0	93	
1 15 0	90	
1 30 0	87	
1 45 0	89	
2 0 0	84	
2 15 0	78	
2 30 0	75	
2 45 0	75	
3 0 0	69	
3 15 0	52	
3 25 0	31	
3 30 0	26	
3 35 0	22	
3 40 0	17	
3 44 0	15	dead.

Simultaneous observations on the arterial blood pressure and the volume of the kidney or spleen following the intravenous injection of the venom.

These experiments were performed on dogs. The animals were given a hypodermic injection of morphia half an hour previously, and inhaled ether during the operative procedure. The carotid artery and jugular vein were dissected out. The former was connected with a mercury manometer, and a cannula tied in the vein by means of which the venom containing solution was introduced. The kidney was reached through the loin, and placed in a Roy's oncometer and surrounded by hot cloths. Instead of using oil as Roy originally did, hot water was used and the membranes enclosing the organ were previously soaked in oil. The oncometer was connected to the piston-recorder by an india-rubber tube with stout walls. Unfortunately the range of movement of the piston-recorder I have worked with is insufficient to register the great variations produced in the volume of the kidney by the injection of snake venom. The spleen was reached by a

long incision at the outer border of the rectus muscle, and placed in Roy's spleen box. Hot water was used to surround the organ, which was prevented from cooling in the same manner as before. In these experiments, however, the piston recorder was discarded owing to its insufficient range, and the end of the rubber tube farthest from the spleen box was connected with a small burette graduated in $\frac{1}{10}$ths of a cc. The level of the water in the burette was adjusted so as to be three inches above the level of the spleen box, in order that the pressure on the outside of the organ should approximately equal the pressure in the splenic vein. During the progress of the experiment, the graduation opposite the level of the water in the burette was read off by an assistant, and at the same time an indication was made on the blood pressure record by raising the signal line. An increase in volume of the organ, due to increase in the capillary pressure within the organ, is indicated by the water flowing into the burette. Diminution in volume is indicated by a corresponding flow out of the burette. By reading off the increase or diminution in the water in the burette, a measure of the alteration in volume is obtained.

In tabulating the graphic records, the height of the arterial pressure curve has been measured as before, and in the spleen volume experiments, the volume in cc. by which the organ was diminished, has been placed opposite the value of the arterial blood pressure at the moment. With the kidney experiments the value of the ordinates on the curve in cc. was ascertained by observing the extent of rise or fall of the lever of the piston recorder which corresponded with the entrance or exit of 1 cc. of fluid into the piston box. This tabulation is not quite accurate, owing to the lever moving in an arc, and therefore the value of the ordinates is not uniform, but this error may be neglected for the present purpose.

In observing the volume at any particular time, the maximum value and minimum value of the respiratory undulations were both recorded and the mean taken. With the spleen experiments the variations in volume caused by the rhythmic contraction of the

organ itself, were accounted for in the same way. These contractions diminished or disappeared when the arterial pressure sank greatly after the introduction of the poison, and reappeared in those cases in which the pressure temporarily recovered, to vanish again as the pressure finally sank.

Experiment 30—Dog, weight 13·5 kilos.; curarised; artificial respiration; carotid connected with a mercury manometer; vagi cut; poison introduced through a cannula in the external jugular vein; right kidney placed in oncometer.

Time. hrs. mins. secs.	Blood pressure in mm.	Volume of kidney.	Remarks.
Normal	146	normal	·000035 gramme per kilo. injected into jugular vein.
0 0 30	103	−1 cc.	
0 1 0	81	−2·1 cc.	
0 2 0	64	*	
0 3 0	55	*	
0 4 0	52	*	
0 5 0	44	*	
0 6 0	40	*	
0 10 0	32	*	
0 15 0	30	*	
0 17 0	18	*	dead

* Denotes that the diminution in volume of the organ is greater than the piston-recorder could indicate.

Experiment 31—Dog, weight 9 kilos.; hypodermic injection of 2 grains of morphia acetate; ether; vagi cut; carotid connected with mercury manometer; poison introduced through a cannula in external jugular vein; right kidney placed in oncometer.

Time. hrs. mins. sees.	Blood pressure in mm.	Volume of kidney.	Remarks.
Normal	120	normal	·000015 gramme per kilo. injected into jugular vein.
0 1 0	96	−1·8 cc.	
0 5 0	73	*	
0 10 0	75	*	
0 20 0	90	*	
0 25 0	106	−1·8 cc.	
0 30 0	112	−6 cc.	
0 42 0	108	−7 cc.	animal bled to death.

* Denotes that the diminution in volume of the organ is greater than the piston-recorder could indicate. During this time its lever described a straight line on the drum. As the pressure again rose the piston recommenced to describe the characteristic volume curve, exhibiting the cardiac and respiratory undulations.

Experiment 32—Dog, weight 3·6 kilos.; $\frac{1}{2}$ grain morphia injected hypodermically; ether; vagi cut; carotid connected with a mercury manometer; poison introduced through a cannula in external jugular vein; spleen placed in oncometer. Volume of spleen when dead = 30 cc.

Time. hrs.	mins.	secs.	Blood pressure in mm.	Volume of spleen.	Remarks.
Normal			133	normal	·0001 gramme per kilo. injected into jugular vein.
0	0	30	112	−0·8 cc.	
0	1	0	82	−1·8 ,,	
0	3	0	58	−2·1 ,,	
0	5	0	52	−2·0 ,,	
0	10	0	79	−1·6 ,,	
0	20	0	105	−0·9 ,,	
0	30	0	122	−0·4 ,,	
0	45	0	101	−0·8 ,,	
1	0	0	95	−0·8 ,,	
1	30	0	63	−1·6 ,,	
2	0	0	41	−1·9 ,,	
2	10	0	31	−2·0 ,,	
2	15	0	28	−2·0 ,,	
2	17	0	23	−2·0 ,,	dead.

Experiment 33—Dog, weight 4·3 kilos., 1 grain morphia hypodermically; ether; vagi cut; carotid connected with a mercury manometer; poison introduced through a cannula in the external jugular vein; spleen placed in oncometer. Volume of the spleen when dead = 36·5 cc.

Time. hrs.	mins.	secs.	Blood pressure in mm.	Volume of spleen.	Remarks.
Normal			120	normal	·000075 gramme per kilo. injected into jugular vein.
0	0	10	107	−0·5 cc.	
0	1	0	73	−2·0 ,,	
0	3	0	58	−3·1 ,,	

Time. hrs.	mins.	secs.	Blood pressure in mm.	Volume of spleen.	Remarks.
0	10	0	102	−0·8 ,,	
0	15	0	110	−0·3 ,,	
0	30	0	108	−0·3 ,,	
0	45	0	103	−0·4 ,,	
1	0	0	96	−0·9 ,,	
1	30	0	97	−0·9 ,,	
2	0	0	91	−1·0 ,,	
2	30	0	65	−2·2 ,,	
2	40	0	58	−2·9 ,,	
2	50	0	54	−3·1 ,,	
3	0	0	50	−3·3 ,,	
3	30	0	42	−4·0 ,,	
3	40	0	36	−4·0 ,,	
3	50	0	32	−4·0 ,,	
4	0	0	27	−4·1 ,,	
4	13	0	18	−4·2 ,,	dead.

V.—Effect of Venom on the Nervous System.

The venoms of all snakes directly, or indirectly affect the nervous system. The introduction of snake poison is followed by depression, faintness, loss of co-ordinating power, and ultimately by paralysis. These symptoms point to alteration in either the nervous centres or the peripheral nerves.

Brunton and Fayrer concluded, from their experiments, that the peripheral termination of the motor nerves were actually paralysed by cobra venom. These authors repeated Claude Bernard's classical experiments by means of which he demonstrated that curare paralysed the peripheral terminations of motor nerves. The results with cobra venom showed that this poison exerted a similar effect. They were however, of opinion that paralysis of motor nerves was not the only effect of cobra poison on the nervous system, but that the spinal cord was also paralysed. In some instances paralysis of the spinal cord appeared to cause death, when little or no affection of the motor nerves could be observed, but in other cases the peripheral paralysis was strongly marked. They thought it was doubtful whether the cerebrum was directly affected by the poison, as the intelligence both in man and in animals often remained unimpaired to the last, and

the stupor and drowsiness which were sometimes noticed, might have been caused indirectly.

According to Wall,[1] the principal action of cobra poison on the nervous system, consists of an extinction of functions extending from below upwards, of the various nerve-centres constituting the cerebro-spinal system ; and though, no doubt, other parts of the nervous system suffer, this poison acts especially on the respiratory centre, and on those other ganglia allied to it in the medulla oblongata, which are in connection with the vagus, the spinal accessory, and the hypo-glossal nerves, and it is directly to this destructive action that we have to attribute death in most cases of cobra poisoning.

Wall found, however, that there were marked differences between the actions of the poison of the cobra, and *Daboia russelii*, (a viperine snake) upon the nervous system. The poison of the latter almost always occasioned violent convulsions, which were not due as in cobra poisoning to failure of the respiration. They occurred quite suddenly, and were in no way obviated by artificial inflation of the lungs. Sometimes the animal died at once, sometimes after a partial recovery. Wall thought these convulsions were caused by the direct operation of the poison on the nervous system and not by asphyxia. Nevertheless, I feel convinced that they were in reality asphyxial convulsions, and due to intravascular clotting, whereby the circulation was impeded, or altogether stopped.

Another very interesting fact discovered by Wall was that if *Daboia* venom was heated to 100° C. its power of producing these convulsions was abolished. Injection of the boiled poison caused a gradual cessation of the respiration, followed by a few convulsions, due to respiratory failure.

Exactly the same result is obtained by heating *Pseudechis* venom to 85° C., and I have already shown that this is because its capacity to occasion intravascular clotting has thereby been almost destroyed.

1 "Indian Snake Poisons."

Feoktistow on the other hand, experimenting with the venoms of *Crotalus* and *Vipera berus*, found that even when complete paralysis of the extremities had occurred, faradisation of the peripheral end of a nerve produced perfectly normal contractions of the muscles, and he was unable to find any interference with the passage of nerve impulses to voluntary muscles. (No curare effect).

These venoms produced a gradual paresis, involving, as a rule, the hinder extremities first, and soon passing into a condition of complete paralysis. The reflexes disappeared either before, or at the same time as the onset of paralysis. He was unable to restore the diminished or lost reflex activity of the cord by even intravenous injections of strychnine; nor could he produce any movement of the opposite limb by faradaic stimulation of the central end of the sciatic nerve, even when the paralysis of the hind limbs was still incomplete. During the later stages of poisoning he observed dilation of the pupil.

Ragotzi[1] has recently, by an extensive series of experiments on frogs, confirmed the results obtained by Brunton and Fayrer, as to the action of cobra venom on the peripheral termination of the motor nerves. He has also by some ingenious experiments shown that the same occurs in mammals, and is of opinion that to this peripheral paralysis the nervous symptoms are almost entirely due. In summing up the results of his experiments he says—"Ich glaube daher, dass durch das Najagift eine specifische primäre Lähmung der nervösen Centra nicht hervorgebracht wird. Trifft sie irgendwo in die Erscheinung, dann ist sie wohl nur secundarer Natur, d. h. die Folge von schweren Circulationstörungen."

When *Pseudechis* venom is introduced into an animal, after a period of uneasiness which varies according to the amount injected, it becomes sleepy and lethargic, and if a dog, it vomits. The lethargy increases, and is succeeded by weakness, which is at first most manifest in the hind quarters. The animal remains quiet,

[1] *Loc. cit.*

and disinclined to move. If made to walk its gait is unsteady, and accompanied by incoordination of movement. At the same time it responds less readily to any form of stimulation, and its senses appear dulled. Later it is quite unable to stand, the pupils become dilated and insensible to light, and the breathing shallow and slowed. In this condition it responds sluggishly to painful stimulation, although the skin and corneal reflexes, and movements evoked by stimulation of the sensitive hair of the snout, are still rapidly produced. Eventually no response can be evoked by stimulation from any of the surfaces, and the corneal reflex disappears last. By this time the respiratory movements have become very sluggish, and with the exception of occasional long inspiratory gasps, greatly diminished in extent. The respiration ultimately ceases when with or without a few feeble convulsive movements, the animal succumbs.

I have already shown that the venom paralyses the heart, and thereby gradually depresses the circulation, and it is quite conceivable that all these nervous symptoms could be produced by a gradually diminished blood supply to the central nervous system. Accordingly, before we can draw any conclusions as to how far these results are due to a direct interference with the function of the nervous system, it will be necessary to eliminate the operation of this factor.

By varying the conditions of the experiment, it is however easy to show that, although in many cases the circulatory depression contributes to the gradual extinction of function of the nervous system, the venom does itself exert a very powerful action upon the medulla and cord, and more especially upon the respiratory centre.

When the venom reaches the circulation in a considerable quantity at one time, the heart is the more affected, whereas the respiratory centre is sensitive in a higher degree to the continuous operation of the poison in small concentration. This conclusion was arrived at from the fact that in those cases where the poison is rapidly introduced into the circulation, as when small quantities

intravenously, or large quantities subcutaneously, are injected, the more obvious effect is that produced upon the heart, but if the delivery of the venom be slower, as when it is subcutaneously injected, in not too large amount, the function of respiration is the one more particularly interfered with, whilst the circulation may be well maintained. In fact, were two separate observers to experiment, the one with intravenous, the other with subcutaneous injections, the conclusion of the former would be that the principal action of the venom was that of a cardiac poison, while the latter might consider that any interference with the circulation was altogether subsidiary to the action of the poison on the respiratory mechanism.

Different species of animals also exhibit some variation in the relative degree of sensitiveness of their vascular and respiratory mechanisms to the poison. In dogs the effect on the vascular mechanism is, under similar conditions, generally more manifest than in rabbits, whereas the latter appear to be particularly sensitive to the influence of the poison in that portion of the nervous system connected with respiration. It must, however, be distinctly understood, that in all animals the venom produces a profound paralysing effect upon the heart, and even in rabbits, life can be prolonged but a few minutes by means of artificial respiration. In those experiments in which immediately any signs of diminished respiratory activity were obvious, artificial inflation with warmed air was resorted to, the blood pressure fell to within a few mm. of zero, and the animal died very shortly after extinction of ordinary breathing had occurred.

It would appear as if the poison must reach a certain proportion in the circulating blood, before it can seriously interfere with cardiac contractions, but once this proportion is reached, the heart is very speedily and profoundly affected. When the absorption of the venom is slow, it may however effect a gradual paralysis of the more sensitive respiratory nervous mechanism, before it is present in the blood in sufficient concentration to produce any appreciable diminution in cardiac activity.

It is not, however, so easy to eliminate the influence of deficient circulation, as a possible cause of the symptoms of general paralysis of the cord which occur in poisoned animals, because the rest of the nervous system does not exhibit the same degree of sensitiveness as the respiratory centre. Nevertheless, one may infer that a poison which produces so deadly a paralysing effect upon a special group of nerve cells, will exert the same influence though in lesser degree upon the rest of the nervous system. There is indeed absolute evidence of this, in the case of cold-blooded vertebrates, such as frogs, and although with mammals the evidence is not so completely satisfactory, it nevertheless leaves no reasonable doubt that a diminution of the reflex activity of the cord, due to the direct action of this venom on the nerve cells, exists after the injection of the poison.

In the section devoted to the consideration of the effect of the poison on the circulation, I stated that after the introduction of venom into a vein, a great fall of blood pressure occurred, which was accounted for by a direct paralysing effect of the poison upon the heart. When, however the quantity injected was a small one, the blood pressure very soon regained its former height, and the circulation was as well maintained as previously. Nevertheless the condition of the nervous system of the animal is very different to that immediately preceding the injection. When removed from the table it shows great weakness, and is often unable to walk, or even to stand, but lies helplessly in any position in which it may have fallen after a few incoordinate attempts to regain a normal attitude. Its tendon reflexes are feeble or altogether absent, and it reacts sluggishly to any form of cutaneous stimulation.

Rabbits of about two kilogrammes in weight, which have received ·01 gramme of venom subcutaneously, die in from two to three hours. The immediate cause of death, as I shall presently show, is due in most cases to respiratory failure. If, directly the respiration becomes shallow, artificial inflation of the lungs be employed, they live some fifteen or twenty minutes longer. In

three experiments in which under these conditions a tracing of the arterial blood pressure was taken, this was maintained at, or a very little below the original height, for some ten minutes after the power of the animal to breathe, had absolutely disappeared. In these experiments shortly before the cessation of ordinary respiration the abdominal skin reflex which is so strongly marked in rabbits could no longer be elicited, and its disappearance was followed by that of the corneal reflex also, while at the same time the efficiency of the circulation was maintained, as was shown by the blood pressure remaining as high, or nearly as high as at the commencement of the experiment.

(*a*)—*Effect of venom on the reflex activity of the spinal cord in frogs.*

After the introduction of ·01 gramme of venom into the dorsal lymph sacs of frogs, the animals soon show signs of advancing paralysis. In about ten to fifteen minutes after the inoculation, the respiratory movements become slow, and eventually cease. It now responds only sluggishly to cutaneous stimulation, and if turned over on its back can with difficulty regain the prone position, on account of the incoordination of its efforts. A few minutes later the animal is quite unable to turn over, when placed on its back, and responds slightly or not at all to every form of cutaneous stimulation. In about twenty minutes it is absolutely paralysed, and even stimulation of the central end of a divided sciatic nerve is unable to produce the slightest reflex response.

If a frog in this condition be opened, the heart may be beating feebly, but in most cases the whole circulation is thrombosed. Now it is obvious that one cannot draw any conclusions concerning the direct action of the poison upon the nervous system from such an experiment, as suspension of the circulation produces the same result. Thrombosis may however be obviated, as I have previously mentioned by raising the temperature of the venom solution to 85° C. before injecting it. In the remainder of my experiments on frogs this was done; ·01 gramme of this heated venom never produced thrombosis, but the animals showed the

same symptoms of gradual extinction of function of the nervous system as those inoculated with the unheated venom. When the animals were completely paralysed, the heart was found to be still beating fairly strongly.

To test the effect of venom on the reflex activity of the cord, Ture's method was employed. The brains of seven frogs were destroyed, and the animals were then hung up in a row by the lower jaw. About every five minutes the foot of each frog was dipped in a ·4% solution of sulphuric acid. The moment the foot touched the fluid a chronograph was started, and the moment there was any movement of the leg, it was stopped. The chronograph measured to one-fifth of a second.

The time intervening between the commencement of the stimulation and the beginning of response, (latent period of response), was then noted, and the foot of the frog washed in a beaker of water. The whole process was then repeated with the next frog. As the activity of the cord diminished, the latent period increased. When the seven frogs had been tested three times in this way, ·01 gramme of venom dissolved in ·5 cc. salt solution, and previously heated to 85° C., was injected into the dorsal lymph sac of three of them, and the hearts of two were cut out, while the remaining two served as controls. The effect of the poison, and also the effect of cessation of all circulation upon the latent period of response is shown in the following table, where the columns of figures represent this latent period of response in seconds.

Time.	Frog 1	Frog 2	Frog 3	Frog 4	Frog 5	Frog 6	Frog 7
	Seconds	Seconds.	Seconds	Seconds.	Seconds.	Seconds	Seconds.
3 p.m	2·6	1·8	2·6	2·0	2·0	1·6	2·4
3·5 ,,	1·0	2·2	2·4	1·2	1·2	1·4	1·6
3·10 ,,	0·8	2·8	2·6	·8	1·2	·8	1·8
3·15 ,,	...	...	heart cut out	heart cut out	·01 gramme heated venom injected into lymph-sac.		
3·20 ,,	·6	3·0	2·8	1·0	1·4	1·0	1·8
3·25 ,,	1·0	2·8	2·4	1·0	1·2	1·8	2·2
3·30 ,,	·6	2·2	2·6	1·2	4·6	3·4	4·0
3·35 ,,	·6	2·2	5·2	4·0	no response	5·0	no response
3·40 ,,		3·0	no response	6·8	,,	no response	,,
3·45 ,,	·8	3·0	,,	no response	,,	,,	,,
Next day	3·4	4·2	,,	,,	,,	,,	,,

While with the control frogs there was no very marked alteration in the reflex excitability of the cord until the next day, those frogs in which the circulation was abolished failed to respond in twenty-five and twenty minutes after the suspension of the circulation. For the few minutes previous to the absence of response to stimulation, the latent period was increased. The poisoned frogs whose hearts were still beating moderately after the cessation of all reflex activity, however, ceased to respond after fifteen and twenty minutes; that is sooner than those in which the cord was deprived of all blood supply. Under these circumstances the effect on the nervous system must have been a direct one, and wholly independent of any interference with the vascular mechanism.

(*b*)—*The effect of the venom on motor nerves.*

The general features presented by an animal poisoned with the venom are strikingly similar to those which follow the injection of curari. The gradual cessation of all motor phenomena either of a spontaneous or reflex origin might very well be due to the poison operating in this way. The conclusion of Brunton and Fayrer, and Ragotzi, that cobra poison paralysed the peripheral ends of the motor nerves, lends additional support to such a view.

With the object of investigating this point, I made a number of observations on frogs poisoned with the venom, in the same way as the action of curari was determined by Claude Bernard. I also determined whether there was any evidence of such interference with the terminations of the phrenic nerves, and also with the motor nerves of the brachial plexus of rabbits. Ragotzi found that the terminations of the phrenics were more sensitive to the action both of curari and of cobra poison, than the other motor nerve endings; and he sees in this increased sensitiveness the reason why so many observers have attributed a selective action upon the respiratory centre to cobra venom.

I have both with frogs and mammals been quite unable to discover any indication that *Pseudechis* venom produces an effect

upon motor nerve terminations. The symptoms of interference with the nervous system cannot be accounted for in this way.

(i.)—*Experiments with Frogs.*

In all these experiments the sciatic nerve on one side was dissected out for a length of about 1 cm. and a ligature passed under it and tied around the limb, but so as to exclude the nerve. The poison was then introduced either into the dorsal lymph sac, or into the peritoneal cavity, and was unable to reach the ligatured limb which was cut off from all circulation. As soon as all movement either voluntary or reflex had ceased, the lower half of the frog was cut off at the waist, the skin removed from the lower half of the body and the sciatics of both sides stimulated as they lay beside the urostyle in the abdominal cavity.

The capacity of the nerve to conduct impulses to the muscle, was ascertained by stimulating it with the induced current from a Du Bois Reymond's coil, and recording the greatest distance of the secondary from the primary coil when a contraction of the gastrocnemius was caused by breaking the primary circuit. This circuit contained one Daniel cell, and a moderately constant rapidity in opening the circuit was obtained by allowing a rotating cylinder to make and break a metallic contact. The cylinder was kept rotating at a uniform speed, and made and broke circuit with each revolution. The secondary circuit was short circuited by a Du Bois Reymond key. This was opened, when it was wished to stimulate the nerve, during one revolution of the cylinder, and then closed again. As only the minimal stimuli requisite to produce a contraction were employed, the closing of the primary circuit just previous to its opening, failed to cause any contraction of the muscle.

Experiment I.—Large male frog, weight 21 grammes; left leg ligatured but so as to exclude the sciatic nerve.

2·37 p.m., ·25 cc. of a 1% solution of *Pseudechis* venom injected into dorsal lymph sac.

3·20 „ both legs kicked when foot was pinched.

4·0 p.m., both legs kicked when foot was pinched.
5·0 „ ditto ditto
7·0 „ responds sluggishly to stimulation; recovers with difficulty when placed on back.

Next morning the frog was quite lively.

In this experiment the condition of the nerves was not tried as an insufficient amount of venom had been inoculated.

Experiment II.—Sturdy male frog, weight 18 grammes prepared as in Experiment I.

12·2 p.m., ·5 cc. of 1% solution of venom injected into dorsal lymph sac.
12·20 „ respiratory movements ceased; pinching foot of unligatured limb causes it to be drawn away slowly.
12·21 „ when turned over on its back makes no attempt to regain the prone position.
12·24 „ corneal reflex gone.
12·25 „ sciatic nerves prepared for stimulation.

Maximum distance of secondary from primary coil when gastrocnemius contracted.

	Electrodes on sciatic nerve.	Electrodes on dorsal cord.
Ligatured limb...	47 cm.	32 cm.
Unligatured limb	58 cm.	38 cm.

Experiment III.—Large female frog, weight 19 grammes, prepared as before.

12·40 p.m., ·5 cc. of 1% solution of *Pseudechis* venom injected into dorsal lymph sac.
12·56 „ respiratory movements ceased.
1·0 „ when turned over on back unable to recover prone position.
1·5 „ all reflex movements absent; sciatic nerves prepared

Maximum distance of secondary from primary coil when gastrocnemius contracted.

	Electrodes on sciatic nerve.	Electrodes on dorsal cord.
Ligatured limb...	63 cm.	33 cm.
Unligatured limb	59 cm.	33 cm.

I found that the venom had occasioned intravascular clotting in both these frogs. The blood in the whole vascular system was coagulated, *except in the ligatured limb.* It therefore appeared quite likely that the venom had not been circulating sufficiently long to produce any influence on the nerve terminations. In the remainder of the experiments intravascular clotting was obviated by using venom which had previously been heated to 85° C. for a minute. Nevertheless the same paralysis followed, but it took considerably longer to develope when the same weight of poison was employed.

Experiment IV.—Large male frog, weight 20 grammes, prepared as usual.

12·15 p.m., ·5 cc. of 1% solution of venom previously heated to 85° C. injected into dorsal lymph sac.

4·30 „ respiratory movements feeble; recovers with difficulty when placed on back.

5·30 „ respiration ceased.

7·0 „ no response to stimulation; sciatics dissected out.

Maximum distance between coils when gastrocnemius contracted.

	Electrodes on sciatic nerve.	Electrodes on dorsal cord.
Ligatured limb...	22 cm.	19 cm.
Unligatured limb	62·5 cm.	27 cm.

Experiment V.—Lusty frog, weight 18 grammes prepared as usual.

3·20 p.m., ·75 cc. of a 1% solution of venom previously heated to 85° C. injected in dorsal lymph sac.

3·30 „ respiratory movements ceased. Moves both legs slowly when feet are pinched; turns over with difficulty when placed on back.

3·34 „ remains on back without attempting to recover.

3·37 „ all reflex response gone; sciatics dissected out.

Maximum distance between coils when gastrocnemius contracted.

	Electrodes on sciatic nerve.	Electrodes on dorsal cord.
Ligatured limb...	53 cm.	34 cm.
Unligatured limb	60 cm.	39 cm.

Experiment VI.—Frog (male), weight 20 grammes, prepared as usual.

4·30 p.m., ·5 cc. of a 2% solution of venom previously heated to 85° C. injected into dorsal lymph sac.

4·45 „ respiratory movements ceased; recovers with difficulty when placed on back.

4·50 „ all reflexes absent; sciatics prepared for stimulation.

Maximum distance between coils when gastrocnemius contracted.

	Electrodes on sciatic nerve.	Electrodes on dorsal cord.
Ligatured limb...	75 cm.	37 cm.
Unligatured limb	79 cm.	34 cm.

Experiment VII.—Frog (female), weight 18·5 grammes, prepared as usual.

4·30 p.m., ·5 cc. of a 2% solution of venom previously heated to 85° C. injected into dorsal lymph sac.

4·40 „ respiration shallow; reflexes dull; recovers with difficulty when laid on back.

5·5 „ no reflex response; sciatics dissected out.

Maximum distance between coils when gastrocnemius contracted.

	Electrodes on sciatic nerve.	Electrodes on dorsal cord.
Ligatured limb...	61 cm.	32 cm.
Unligatured limb	58 cm.	33 cm.

In nearly the whole of these experiments the contraction of the gastrocnemius was induced by a less stimulus in the poisoned than in the unpoisoned limb. Had the poison exerted any effect analagous to that produced by curari, the opposite result would have been observed. The diminished sensitiveness of the muscles in the ligatured limb is explained by the fact that all circulation had been cut off since the application of the ligature. The longer the time which had elapsed since the limb was tied, the greater was the difference in sensitiveness between the two sides.

Experiments to determine whether the venom affects the motor nerve terminations of mammals.

Ragotzi came to the conclusion that the terminations of the phrenic nerves in the diaphragm were more sensitive both to the action of cobra venom and curari than the endings of the motor nerves in the muscles of the limbs. I accordingly chose the phrenics for the purpose of ascertaining whether *Pseudechis* venom in any way affected the passage of nervous impulses through motor-nerve terminations.

When a dose of ·005 to ·01 gramme of venom per kilogramme of the animal's weight is injected either subcutaneously, or into the peritoneal cavity of a rabbit, within a few hours the respiratory movements are much diminished both in rate and in extent The diaphragmetic contractions become progressively weaker, until they disappear altogether, and after a few feeble convulsions, the animal dies of asphyxia. If artificial respiration be resorted to, the convulsions speedily cease. Nevertheless, artificial inflation does not prevent the death of the animal, which occurs within a few minutes from circulatory failure.

I have already shown that this gradual failure of all respiratory movement is not essentially dependent upon any alteration in the circulation. It might however, be occasioned either by paralysis of the respiratory centre, or by interference with the passage of nerve impulses along the phrenics to the diaphragm, as Ragotzi maintained was the case in cobra poisoning.

To test the latter alternative, I arranged a series of experiments in which I determined the least stimulus which, when applied to the phrenic, would cause a contraction of the diaphragm, both before injection of the poison and at intervals afterwards, until spontaneous respiration had entirely disappeared.

As the venosity of the blood from the failing respiration would itself produce a diminution in the excitability of the muscular fibres of the diaphragm, the complete aeration of the blood was secured by artificial inflation of the chest with warm air, and as

enfeeblement of the circulation would also operate in the same manner, a simultaneous record of the blood pressure was taken in order to keep a check on this possible source of error.

Rabbits of about $1\frac{1}{2}$ kilogrammes in weight were used. The carotid artery was connected with a mercury manometer, and a glass cannula tied into the trachea. The glass cannula communicated with a Marey's tambour, the artificial respiration apparatus, and the external air by three taps. By means of the tap connected with the respiration apparatus, artificial inflation could be turned on or off at a moment's notice. The lever of the tambour and a float with scribe on the mercury manometer registered on a travelling surface, the respiratory movements and the blood pressure respectively. The left phrenic nerve was dissected out in the neck, and placed upon electrodes. The nerve was prevented from drying by being, together with the electrodes, again covered with the skin. The phrenic was stimulated by the induced current from the secondary terminals of a Du Bois Reymond's coil, and the primary circuit was broken by the same arrangement, as was used in the experiments with frogs, described above. In the primary circuit was a Daniel cell. At the commencement of each experiment a record of the respiration, blood pressure, and the greatest distance between the coils of the inductorium when a contraction of the diaphragm followed stimulation of the phrenic was obtained. It was not found necessary to open the abdomen and observe the diaphragm directly, as when a contraction of the left half of the diaphragm occurred, there was an unmistakeable sharp movement of the fur on that side, owing to the sudden retraction of the lower ribs. The same series of observations were made every fifteen minutes after the injection of the poison, and as soon as the respiration exhibited any signs of failure, artificial inflation was brought into action by turning the tap connected with the respiration pump. The animal's capability to breathe by itself was recorded every fifteen minutes by turning off the artificial respiration for a few seconds. In the tabulated account of experiments I have employed the extent of the respi-

ratory excursions of the tambour, as a measure of the condition of its respiratory mechanism. This does not however, indicate the total disablement, for the respirations were diminished in number as well as extent.

Experiment I.

	Distance between coils.	Amplitude of respiratory record.	Remarks.
Before injection... ..	46 cm.	12 mm.	
15 minutes after		15 „	
30 „			
45 „			
1 hour 10 „	47 cm.		
„ 15 „	49 „	10 mm.	respiration slowed.
„ 30 „	49 „	8·5 „	„ „
„ 45 „	49 „	6 „	„ „
2 hours 0 „	49 „	5·5 „	„ very slow.
„ 15 „	45 „	4 „	circulation began to fail.
„ 30 „	44 „	2 „	
„ 45 „	42 „	·5 „	
3 hours 0 „	36 „	0 „	

Experiment II.

	Distance between coils.	Amplitude of respiratory record.	Remarks.
Before injection... ...	35 cm.	14 mm.	
15 minutes after		20 „	
30 „		14 „	respiration much slower
45 „	36 cm.	15 „	„ „
1 hour 0 „	36 „	14·5 „	„ very slow.
„ 15 „	29 „	2 „	blood pressure fallen; corneal reflex gone; respiration very slow.
„ 30 „	30 „	·5 „	
„ 35 „	30 „	0	

Experiment III.

	Distance between coils.	Amplitude of respiratory record.	Remarks.
Before injection... ...	41 cm.	15 mm.	
15 minutes after		17 „	
30 „	41 „	22 „	
45 „		23 „	
1 hour 0 „	40 „	26 „	
„ 15 „	42 „	26 „	
„ 30 „	42 „	14 „	
„ 45 „	42 „	10 „	respiration slowed.

Experiment III.—*continued.*

	Distance between coils.	Amplitude of respiratory record.	Remarks.
2 hours 0 minutes after	42 cm.	10 mm.	respiration slowed.
„ 15 „	42 „	7 „	
„ 30 „	40 „	4 „	
„ 45 „	41 „	3·5 „	
3 hours 0 „	40 „	·5 „	corneal reflex gone.
„ 15 „	41 „	0	blood pressure as high as at beginning of experiment.
„ 30 „	36 „	0	blood pressure falling.

Experiment IV.

	Distance between coils.	Amplitude of respiratory record.	Remarks.
Before injection... ...	42 c.m.	16 mm.	
15 minutes after	42 „	19 „	
30 „		11 „	
45 „		10 „	blood pressure falling.
1 hour 0 „	40 „	4 „	„ „
„ 15 „	37 „	2 „	abdominal reflex gone.
„ 30 „	30 „	·8 „	corneal reflex gone; pressure fallen to half.
„ 45 „	30 „	0	

In all of these experiments, the strength of the stimulus requisite to cause a contraction of the diaphragm, when applied to the phrenic nerve, was slightly greater at the end of some hours. The difference was however, very slight, and it is noteworthy that in the only case where the circulatory efficiency was maintained, the strength of stimulus required was the same as at the beginning of the experiment three and a half hours earlier, whereas all spontaneous respiratory movement had ceased fifteen minutes before. One would expect to find that the mere fact of having a nerve on electrodes all this time would in itself have produced a diminished sensitiveness to stimuli. The experiments I think, show conclusively that *Pseudechis* venom in no way affects the transmission of impulses from nerve to muscle.

VI.—Effect of the Venom on the Respiratory Mechanism.

The effect of cobra poison on the respiration has been carefully investigated by Wall who has published some interesting stetho-

metric charts, taken from animals injected with this venom. The first change he noticed in an animal after the introduction of cobra poison, was a decided quickening and deepening of the respiratory movement. This increase was no longer to be seen after the section of the vagi. The quickening was only temporary, and after an interval of uncertain duration, the respiratory movement, became slower, and less in extent. This diminution continued until the blood was no longer oxygenated, when the animal died with the usual symptoms characteristic of asphyxiation. When a large dose (1 cc. of fresh venom), was introduced directly into the circulation of a dog, Wall found that thirty seconds after the injection, the animal was suddenly seized with asphyxial convulsions, in which it died in about one hundred seconds. Wall attributed these convulsions to a stimulation of the respiratory centre prior to extinction of the function of the same. This may be the correct explanation of the phenomena, but the injection of *Pseudechis* venom directly into the circulation produces precisely the same series of events, and the explanation in this case is that the whole vascular system is quite suddenly thrombosed.

The gradual extinction of all respiratory movement is, accord- to Wall, due to paralysis of the respiratory centre. Brunton and Fayrer[1] ascribe it partly to this cause, and partly to a curare-like action of the poison on the terminations of the phrenics in the diaphragm, whereas Ragotzi is of opinion that it is due to the latter alone.

Wall[2] has also investigated the action on the respiration, of the poison of the viper *Daboia russellii*. Its action in producing convulsions has already been discussed. If only small doses are subcutaneously injected, or if the venom be previously boiled, the respiration, after a preliminary acceleration, becomes slower and slower, until death occurs.

Mitchell and Reichert[3] found that the venoms of *Crotalus* and *Ancistrodon* caused a primary increase in the number and extent

[1] *Loc. cit.* [2] *Loc, cit.* [3] *Loc. cit.*

of the respirations, followed by a decrease in both. These venoms affected the respiratory rhythm to a much greater extent than the respiratory excursus in the majority of cases.

Feoktistow[1] found a tremendous increase in respiration, followed by asphyxia, after intravenous injection of the poisons of *Crotalus* and *Vipera berus*. His conclusions as to the explanation of these phenomena are not very valuable, as he was undoubtedly dealing with cases of intravascular clotting, although he was quite unaware of such a contingency. He does not appear to have made any observation on the respiration after the subcutaneous injection of the poisons.

After injection of *Pseudechis* venom the respiratory movements become less and less, and ultimately cease. As I have shown that this action of the nervous system may occur independently of any effect on the circulation, and also that the venom has no effect on motor nerves, or their endings in muscle, it must exert its action directly upon the respiratory centre in the medulla. Its action in this respect is best seen when the venom is subcutaneously introduced in rabbits. Under these conditions, the paralysis is often preceded by a period in which the respirations are increased both in number and in extent. The period of increased respiratory activity is much more strongly manifested in some experiments than in others, and is indeed not infrequently entirely absent.

Both Brunton and Fayrer[2] and Mitchell and Reichert[3] state that the primary acceleration of the respirations was absent after cutting the vagi, and the first mentioned observers accordingly attribute this increase in respiratory rhythm to the operation of the poison upon the peripheral terminations of the vagi in the lungs. My results with *Pseudechis* poison are however not in accordance with such a view. The primary acceleration is often absent both in animals with severed, and in those with intact vagi, but occurs with about equal frequency under both conditions. In

---

1 *Loc cit.* 2 *Loc. cit.* 3 *Loc. cit.*

experiments in which the acceleration in rhythm and increase in amplitude of the respirations have been very pronounced, severance of both vagi has had no influence upon the amplitude, and only a slight retarding effect upon the rate. The diminution in frequency of the respirations so produced, have not however been proportionately more than occurs after severance of the vagi in unpoisoned animals. I therefore conclude that the increase in respiratory activity which so frequently occurs after inoculation with *Pseudechis* venom, is due to a primary stimulating effect of this poison upon the respiratory centre.

Sometimes these two phases of increased activity and diminished activity alternate, but the latter gradually obtains the ascendency. Eventually the respiratory movements become imperceptible, and unless artificial respiration be immediately resorted to, the animal dies of asphyxia. Just previous to the final cessation of all respiratory movement, it is not infrequently the case that the respirations occur in little groups separated by periods when the breathing is in abeyance.

When the respiratory movements have ceased, the animal is usually seized with a few feeble convulsions during which it makes some inspiratory gasps of very considerable extent, showing that although the respiratory centre fails to respond rhythmically to the stimulus of blood of such venosity as to powerfully stimulate both the vagus and vaso-motor centres, it does still respond when this becomes excessive.

The more rapidly this cessation of the respiration is effected by the operation of the venom, the more powerful are the convulsive movements just preceding death. In cases of slow poisoning they are altogether absent.

In Experiment 1 of this section, the respiration ceased before the efficiency of the circulation was in any way diminished. This, however, is not generally the case, and although suspension of the respiration usually precedes cessation of the heart-beat, the activities of both these mechanisms decline together. The gradual

enfeeblement of the circulation contributes to the respiratory failure, and *vice versa*, and the simultaneous paralysis of the rest of the nervous system prevents in most cases any marked indication of its asphyxial condition.

Details of experiments to ascertain the effect of the venom upon the respiratory mechanism.

The experiments with this object were performed upon rabbits and dogs. The results were substantially identical with both animals, but the former are much more suitable for the determination of this point, as their respiration is, under normal circumstances, more regular, and the individual respirations do not exhibit the same variations in amplitude as is the case with dogs. Eight experiments on dogs, in which the vagi were previously divided, were made. Of these, only two are here tabulated; the remaining six curves exhibit the same general characteristics as those tabulated, but the respiration both before and after the injection of the poison was so irregular, that although the general effect of the venom is clearly enough seen on looking at the curves themselves, these are unsuitable for reduction to a numerical form. This difficulty is chiefly owing to the fact that after the vagi were severed the respirations occurred in groups. Four or five small respirations occurred together and were succeeded by a deep sighing respiration. In making a table it would be necessary to state the variations in amplitude and rhythm of both kinds of respiratory efforts. Such a table would be difficult to follow, and I have therefore decided to omit the records of these experiments.

The animals were anæsthetised with ether, and the carotid artery connected with a mercury manometer, and the trachea with a Marey's tambour. The style of the manometer and the lever of the tambour wrote upon a Hering's kymograph. The experiments are arranged in three groups: in the first the venom was injected under the skin, in the second into the peritoneal cavity, and in the third series it was introduced directly into the circulation through the

jugular vein. In some cases the vagi were previously severed, in others left intact, or cut during the course of the experiment. Graphic records were obtained in each case, both before and after the injection of the poison, and these curves have been measured and the numbers tabulated. Opposite the time indicated in the first column are placed the amplitude of the respiratory excursion of the tambour-lever, and the number of respirations per minute, together with the blood pressure for the time being.

(*a*)—*Observations on the respiration after subcutaneous injection of the poison.*

Experiment 1—Rabbit, 1·6 kilos. ; vagi intact.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	17	68	106	·005 gramme per kilo. injected under skin of abdomen
0 15 0	15	84	106	
0 30 0	10	68	101	
0 45 0	9	32	96	
1 0 0	7	28	95	
1 15 0	8	28	99	
1 30 0	12	30	97	
1 45 0	23	21	108	large slow cardiac contractions (vagus)
2 0 0	9	28	96	
2 15 0	12	32	91	
2 30 0	11	36	86	
2 45 0	5	33	92	
3 0 0	2·5	24	113	large slow cardiac contractions (vagus)
3 15 0	·5	20	112	ditto
3 17 0	...	...	101	ditto, slight convulsions
3 20 0	...	...	68	ditto, convulsive inspiratory movements
3 23 0	...	...	33	ditto, occasional inspiratory gasps
3 26 0	0	0	16	dead

Experiment 2—Rabbit, 1·1 kilo.; vagi intact; respiration artificial.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	11	72	94	·005 gramme per kilo. injected subcutaneously.
0 15 0	13	76	98	
0 30 0	8·5	56	91	
0 45 0	...	...	90	artificial respiration
1 0 0	...	...	88	ditto
1 15 0	9	48	92	ditto, suspended for 20 seconds
1 30 0	8	40	92	ditto, ditto
1 45 0	6	40	92	ditto, ditto
2 0 0	5	40	93	ditto, ditto
2 15 0	4	35	91	ditto, ditto
2 30 0	1·7	30	85	ditto, ditto
2 45 0	·4	26	56	ditto, ditto
3 0 0	0	0	23	ditto, ditto
3 1 0	0	0	7	dead

In this experiment as soon as the respiration showed signs of failing, artificial respiration was employed. This was discontinued for twenty seconds at intervals during the course of the experiment, and the animals natural respiration recorded. The arrangement of the tubes leading from the artificial respiration pump allowed this to be done, by merely turning off a tap connecting the pump with the trachea.

Experiment 3—Rabbit, weight 1·5 kilos.; vagi cut.

Time. hrs. mins. secs.	Respiration. Amplitude in mm	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	14	44	86	·004 grammes per kilo. injected under skin of abdomen
0 30 0	22	32	86	
1 0 0	20	28	94	
1 30 0	43	40	87	
2 0 0	16	32	90	
2 30 0	14	36	94	
3 0 0	13	36	95	
3 30 0	7	34	91	
3 40 0	5	26	94	
3 45 0	2	22	76	
3 50 0	...	...	64	convulsions
3 52 0	0	0	20	dead

Experiment 4—Rabbit, weight 1·4 kilos.; vagi cut.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	18	40	88	·005 grammes per kilo. injected under skin of abdomen
0 30 0	20	34	89	
1 0 0	32	44	89	
1 30 0	38	40	90	
2 0 0	28	36	89	
2 30 0	15	36	88	
3 0 0	13	45	92	
3 30 0	8	37	94	
3 35 0	7	32	95	
3 40 0	6	18	96	
3 41 0	3	12	108	
3 42 0	3	17	118	
3 43 0	2	16	92	
3 44 0	1	20	74	
3 45 0	...	...	64	slight convulsions
3 46 0	0	0	21	dead

(*b*)—*Observations on the respiration after introduction of venom* ***into the peritoneal cavity.***

Experiment 5—Rabbit, 1·6 kilogramme in weight; vagi intact.

Time. hrs. mins. secs	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	17	52	94	·005 gramme per kilo. injected into peritoneal cavity
0 15 0	10	52	90	
0 30 0	15	101	88	
0 45 0	8	45	84	
0 55 0	5	44	83	
1 0 0	6	49	76	
1 10 0	3	35	61	large slow contractions (vagus)
1 15 0	2	32	55	ditto
1 17 0	...	...	89	convulsions
1 20 0	...	...	42	occasional convulsive gasps
1 21 0	...	...	17	dead

Experiment 6—Rabbit, weight 1 kilogramme; vagi intact.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	17	52	94	·01 gramme per kilo. injected into peritoneal cavity
0 5 0	10	56	60	
0 20 0	8	44	41	
0 30 0	7·5	40	26	
0 35 0	13	32	21	
0 50 0	8	27	20	artificial respiration started
1 5 0	...	...	30	artificial respiration
1 7 0	...	...	27	ditto
1 15 0	...	...	19	ditto
1 25 0	...	...	12	dead

Experiment 7—Rabbit, weight 1·3 kilogramme; vagi intact.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	13	76	90	·01 gramme per kilo. injected into peritoneal cavity
0 10 0	12	74	88	
0 20 0	17	76	78	
0 50 0	15	48	88	
1 5 0	15	40	76	
1 15 0	3	31	50	
1 25 0	2	32	42	
1 30 0	1	30	40	
1 36 0	...	...	36	convulsions
1 37 0	0	0	13	dead

Experiment 8—Rabbit, weight 1·5 kilogramme; vagi intact.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	25	44	110	·01 gramme per hilo. injected into peritoneal cavity
0 10 0	38	60	98	
0 20 0	54	76	96	
0 50 0	9	40	143	
0 51 0	10	37	114	
0 53 0	8	29	118	
0 53 20	...	...	125	convulsions
0 54 0	4	30	51	
0 55 0	0	0	10	dead

(*c*)—*Observations on the respiration after intravenous injection.*

Experiment 9—Rabbit, weight 1·1 kilogramme; vagi intact.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	15	37	98	·01 gramme per kilo. of venom previously heated to 85° C. injected into external jugular vein; injection lasted three minutes.
0 3 0	14	64	86	
0 4 0	6	48	80	
0 5 0	30	81	66	
0 6 0	35	86	44	
0 7 0	15	56	36	
0 8 0	10	40	40	heart beat imperceptible
0 9 0	11	28	34	
0 10 0	...	...	42	convulsions
0 11 0	55	10	8	
0 11 30	...	...	5	dead

In this experiment the activity of the respiration was rhythmical after the injection of the poison. It first became increased in rate and extent, and then diminished in both until it was nearly obliterated, and then again increased (Cheyne-Stokes respiration). The period of these rhythmic alternations was about forty seconds.

The effect of intravenous injection of very small quantities (·00002 gramme per kilo.) of the unheated venom, is precisely similar to the above experiment both upon the blood pressure and upon the respiration. (Compare experiments in the section "Effects of venom on the circulatory mechanism," where the amplitude and rate of the respiratory movements are recorded together with the blood pressure.)

Experiment 10—Dog, weight 5·75 kilos., ·065 gramme morphia hypodermically; vagi uncut; ether during operation.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	24	12	124	·00075 gramme per kilo. injected into jugular vein
0 1 0	32	14	67	
0 15 0	33	12	32	heart beat nearly imperceptible
0 30 0	16	12	44	heart beat increased
0 45 0	14	11	94	ditto
1 0 0	14	8	111	
1 15 0	12	5	48	
1 30 0	10	4	41	
1 40 0	11	3	38	
1 45 0	8	3	37	
1 50 0	7	2	33	
1 51 0	...	...	27	occasional inspiratory gasps
1 52 0	0	0	21	dead

Experiment 11—Dog, weight 5·5 kilos., ·065 gramme morphia hypodermically ; ether during operation ; vagi cut.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	31	6	180	·0005 gramme per kilo. injected into external jugular vein
0 5 0	40	7	90	
0 10 0	42	7	112	
0 15 0	44	8	178	
0 30 0	46	8	172	
0 45 0	46	15	156	
1 0 0	47	16	114	
1 15 0	34	13	80	
1 30 0	25	10	81	
1 45 0	15	11	64	
2 0 0	11	9	30	
2 10 0	0	0	14	dead; respiratory gasps after cessation of the circulation

Experiment 12—Dog, weight 6 kilogrammes, ·065 gramme morphia hypodermically ; ether during operation ; vagi cut.

Time. hrs. mins. secs.	Respiration. Amplitude in mm.	Respiration. Rate per minute.	Blood pressure in mm.	Remarks.
Normal	22	7	163	·0005 gramme per kilo. injected into external jugular vein; injection lasted five minutes
0 5 0	50	5	90	
0 10 0	40	10	110	
0 20 0	41	6	151	
0 30 0	44	4	146	
1 0 0	38	4	108	
1 30 0	26	5	76	
1 45 0	10	6	59	
2 0 0	9	5	56	
2 15 0	6	4	44	
2 30 0	5	4	33	
2 40 0	5	3	28	
2 42 0	...	...	26	slight convulsions
2 44 0	...	...	22	occasional inspiratory gasps
2 45 0	0	0	20	dead

VII.—Effect of the Venom on the Body Temperature.

After the injection of the venom into a warm blooded animal, sometimes a rise, at other times a fall in temperature is observed. The explanation is that the poison influences temperature in two

ways, (1) there is a distinct thermogenic effect which is best seen if a dilute solution of venom in a piece of sterilised sponge, be aseptically inserted under the skin. Under such circumstances absorption is very slow, and one obtains a maximum of local, with a minimum of constitutional effects, and the temperature is invariably raised a few degrees Fahrenheit.

(2) A diminished production of heat under the influence of the profound depression and muscular resolution which usually follow the injection of the poison, so that the temperature may often be observed to be below 90° just previous to death.

As found by Sewall[1] with *Crotalus* poison, an animal rendered resistant to this venom by repeated injections of small non-lethal doses, is able to withstand the effects of a quantity which would inevitably cause death in an animal not so treated. The injection of the lethal dose may under these circumstances be followed by a considerable rise in temperature instead of the depression, which occurs in animals which have not been accustomed to the poison. Calmette[2] has recorded the same fact from his experiments with cobra poison.

VIII.—Further Pathological Effects.

If the nervous symptoms which result from cobra poisoning are recovered from, convalescence is wonderfully abrupt. With the exception of the local blood-tinged œdema in the subcutaneous tissue, which does occasionally suppurate, there would appear to be no further pathological effects. The excretion of the poison by the kidneys does not excite pathological changes in these organs, as witnessed by the absence of albuminuria, and the fact that no alteration in kidney structure has been observed.

With the viperine snakes the case is very different. After the immediate danger of cardiac and respiratory paralysis has passed, the animal suffers from great local and wide spreading hæmorrhage and œdema, which almost invariably suppurates, or becomes gan-

[1] Journal of Physiology, Vol. VIII.

[2] Ann. de l' Institut Pasteur, May, 1895.

grenous. The victim is, in addition subject to hæmorrhages in nearly all the organs, and from all the mucous membranes of the body, together with bloody effusions into cavities such as the pleura and pericardium.

Weir Mitchell and Reichert, in their monograph on snake poisons, have given an extensive record of the various situations in which they have found hæmorrhages after the injection of the poisons of *Crotalus* and *Ancistrodon*. Their observations on the mechanism of these hæmorrhages have already been referred to.

In cases in which the animals died some days after the injection, the post-mortem examination disclosed extensive ecchymoses in the viscera, and hæmorrhages at the base of the brain, and into the serous cavities and lungs.

Wall[1] found that even in rapid cases of *Daboia* poisoning, hæmorrhages into viscera, and from mucous membranes were exceedingly common. When small doses of the venom were subcutaneously inoculated, it was not unusual for an animal to die in consequence of these secondary pathological changes alone, and when not a single nerve symptom had occurred. In contrast to cases of cobra poisoning, albuminuria, or hæmaturia, usually resulted, if the victim lived any time. Speaking of poisoning by Indian viperine snakes, Wall says—"We may conclude then, that in this form of poisoning, when the nerve effects have passed away, there remains a period of blood poisoning, as fatal to life as the nerve symptoms themselves." Wall found that the poison of the *Bungarus fasciatus* produced a form of chronic poisoning, which was remarkable for having an incubation period of from two to six days. After recovering from the immediate depressing effect of the poison, the animal enjoyed a period of perfect health. Then occurred loss of appetite, great depression, and diminution of urinary secretion, with rise of temperature and great muscular weakness. Purulent discharges took place from the eyes, nose, and rectum, but there was no tendency to hæmorrhage. The

[1] "The Nature of Snake Poison, &c."

urine was albuminous, but contained no blood pigment. Death occurred from exhaustion.

These observations of Wall are very interesting, and in no way resemble the operation of any other snake venom so far recorded, but as he points out, remind one of some infectious disease. Perhaps they are indeed directly attributable to the operation of some organisms, which have gained access, owing to diminished resistance caused by the venom. In this respect Ewing's[1] observations on the disappearance of the germicidal properts of serum after poisoning by *Crotalus* venom, are suggestive.

Feoktistow[2] confirmed Mitchell's observations on the extensive hæmorrhages in many of the organs, after the introduction of *Crotalus* poison, and he found the same conditions followed, when the poison of *Vipera berus* was used. This observer never saw any hæmorrhages in the central nervous system, but the conditions of the brain and cord were very seldom investigated. He came to the conclusion that the severity of the hæmorrhagic process was dependent upon the quantity of venom introduced, and the time which elapsed before death occured; and he summed up his remarks on this subject with the following statements: --

(1) "By poisoning with large doses of concentrated venom, hæmorrhages were very severe and extensive, even when the animal only survived a few seconds."

(2) "By medium doses which killed in two to three hours, the hæmorrhages with cats were usually confined to the endocardium and lungs; whereas with dogs, extensive hæmorrhages were to be found in nearly all the organs."

(3) "By minimal lethal doses the pathological changes are greater the longer the animal lives."

(4) "Intravenous injection is much more active in causing hæmorrhages than when the poison is subcutaneously introduced, whereas, after the bite of the reptile (concentrated venom) the hæmorrhages are as marked as after intravenous injection."

---

[1] *Loc. cit.* [2] *Loc. cit.*

The further pathological effects of *Pseudechis* venom arise in three ways—

(1) Those due to the direct action of the venom on the cells of the affected part.

(2) Those secondary to hæmorrhage.

(3) Those secondary to thrombosis.

As regards its power to induce anatomical changes in the victim, *Pseudechis* venom appears to occupy a position about midway between cobra poison and the poison of the viperine snakes.

Its action in separating the hæmoglobin from the corpuscles has already been described. The free hæmoglobin finds its way out of the body, through the kidneys and liver, and so is found staining the urine and bile, in the former of which it is often present in crystalline form. It also passes into the fluid contained in the pericardium, and other serous sacs, and even into the aqueous humour. The staining of all these fluids is independent of any hæmorrhagic action of the venom, and has been of almost constant occurrence in my experiments with different kinds of animals, whenever they have lived more than one to two hours.

I have already shown that this venom affects the endothelial wall of the blood vessels, so as to permit of the escape of their contents, and although it does not appear to be nearly so active in causing hæmorrhages as that of *Crotalus*, or other viperine snakes, extravasations of blood into important organs and hæmorrhages from the mucous surfaces, do however sometimes play an important part in the symptoms of poisoning. The distribution and extent of the hæmorrhages vary under the different experimental conditions in exactly the same way as Feoktistow (whose description I quote above), has observed the hæmorrhages following *Crotalus* poisoning to vary. As was found to be the case with the latter poison, dogs are particularly sensitive to this action of the venom. Hæmorrhages are most marked in those animals which live about two days. The operation of the venom in other directions is also most favourable to the occurrence of hæmorrhages, in addition to

the alteration of the vessel wall, the coagulability of the blood is greatly diminished, or altogether in abeyance, so that the blood which escapes clots slowly, or not at all. In addition, the veins in some areas are often thrombosed, thus raising the pressure in the capillaries of that area, and so increasing the extravasation.

I have elsewhere mentioned that when dogs are the animals experimented with, the blood in the portal vein is particularly liable to be coagulated by the action of the poison. When this has happened the whole of the alimentary track is the situation of extensive hæmorhages, and during life the animal passes blood by the rectum, and vomits blood-stained fluid. When the portal vein has not been thrombosed, the alimentary tract does not suffer more than the rest of the organs.

Unless the poison be injected subcutaneously in large amount, or else introduced directly into the circulation, the extravasation of blood into the organs does not play a very important rôle in poisoning by *Pseudechis* venom. There is however one organ which has, in my experiments with mammals never escaped, viz., the lungs. These have invariably been the seat of hæmorrhages of greater or less extent. Sometimes a considerable portion of one or both lungs has been found more or less solid from extravasated blood. Microscopical examination of a hæmorrhagic lung of an animal which has succumbed in a few hours from the injection of the poison, shows portions of the organ infiltrated with blood. The alveoli, interalveolar tissues, and small bronchi appear one mass of blood corpuscles. A similarly affected lung from an animal which had survived two or three days, shows patches of lung, in which the tissues are barely recognisable, and are imbedded in a mass of fibrin, and more or less altered blood pigment. These necrosed areas are surrounded by a ring of small celled infiltration separating it from the healthy lung around.

It is quite possible that some of the hæmorrhagic extravasation into the lungs is associated with thrombosis in the smaller branches of the pulmonary artery.

On two occasions I have seen some rather interesting pathological changes in the liver following injection of the poison. Wooldridge,[1] in 1888, described some changes in the liver, which he had obtained by producing thrombosis of the portal vein through the injection of nucleo-albumens (tissue-fibrinogen). If the animal was killed a few days after the injection, a clot was found in the portal vein, and the liver showed more or less extensive infarctions. When examined after a fortnight, the clot in the portal vein had completely disappeared, and to the naked eye there was no trace of the hæmorrhages, but microscopical examination revealed scattered patches of early cirrhosis of a greater or less extent.

Precisely the same result occasionally follows the injection of venom. Two dogs which were killed by a second subcutaneous injection of poison fourteen days and twenty days respectively after they had received the first, both showed interstitial cirrhosis of the liver. I was not certain at the time of the first injection, that the portal veins of these dogs had been thrombosed. Such an event is, however a not uncommon occurrence in dogs after the injection of the poison. There was unmistakable evidence that hæmorrhages had occurred in the liver, as the sections showed quantities of altered blood pigment. The pigment was intracellular, and was scattered through the lobules, but was present in greatest amount at their external margins. I think, from the remarkable analogy between these experiments and those of Wooldridge, one may safely conclude that the portal veins had been thrombosed. The dogs were very ill for two days and passed bloody urine, and in one of them a large quantity of blood-stained mucous escaped per rectum. They were both apparently well on the fourth day, and the urine was normal again on the sixth.

There is some evidence to show that cobra poison escapes by the kidneys. I am not yet satisfied that this is the case with *Pseudechis* poison, but my experiments so far, point to this method

[1] Trans. Path. Soc., Lond. 1888.

of exit. When a few milligrammes of venom are injected into a rabbit, it is not an easy matter to find it again, even supposing it has all passed through the kidneys, especially as in these circumstances the urine always contains albumen. The very simple method which has been adopted with cobra poison of inoculating frogs with the urine itself is open to the objection that ·5 cc. of rabbit's normal fresh urine kills the frogs we have in this part of the world with symptoms of paralysis, exactly resembling the effect of venom. Moreover, these frogs are actually more resistant to *Pseudechis* venom than rabbits, notwithstanding the fact that the latter are nearly one hundred times as heavy. Accordingly, even supposing all the venom to have passed into the urine, it would, in most cases, be necessary to inject the whole amount of this fluid, to produce a fatal result, and although one could easily drown the frog in the urine, the other alternative would be an obvious impossibility.

Whether the poison makes its exit through the kidneys or not, these organs are always more or less affected. It is not uncommon to find radial hæmorrhages in the cortex, from the interlobular vessels. The kidneys undergo a further important pathological change which is confined to the cortical portion, and consists in an acute necrosis of the epithelium lining the convoluted tubes. The epithelial cells of these tubes become vacuolated, and then burst, leaving the tubule to a large extent bare of epithelium.

Yet another affection of the kidney remains to be mentioned. The hæmoglobin from the disintegrated corpuscles exhibits an abnormal tendency to crystallise, and this sometimes happens in the tubules of the kidney to such an extent as to block the greater number.

The urine in animals poisoned with *Pseudechis* venom always contains albumen. Very frequently it contains hæmoglobin, and in the more serious cases, blood. Fibrinogen also passes through the kidneys, and in three or four cases of severe poisoning in dogs, I have been able to cause the urine to clot solidly by the addition of a few drops of acetic acid. The blood of these dogs, at the

time, had lost its spontaneous coagulability, and the fibrinogen in the urine did not clot spontaneously, but only after the manipulations which I have already described to induce coagulation in the blood itself under the same condition.

Brief Summary of the Action of *Pseudechis* Poison.

Pseudechis venom is comprehensive in its action. It affects principally the three most vulnerable points in a higher organism; the blood, the heart, and the respiratory centre in the medulla.

Its method of destroying life essentially depends upon the concentration with which the venom reaches the circulation. When this concentration attains a certain limit, death may be almost instantaneous, from coagulation of the blood in the vessels terminating the circulation. This happens when small animals are bitten, or when the poison is introduced in adequate amount directly into the circulation. When the concentration falls short of that necessary to raise the coagulability of the blood to such an extent as to occasion thrombosis, the blood shortly afterwards loses its capacity to clot when shed. In this condition any further injection of venom is unable to produce thrombosis.

The action of the poison upon the heart and respiratory centre is usually simultaneous. With higher concentration of venom the heart is the more rapidly affected, but the continuous operation of the poison in small concentration more quickly affects the respiratory centre in the medulla; so that, by varying the rapidity with which the poison reaches the circulation, the death of an animal may be compassed in any one of three ways: either by clotting the blood in the vessels, cardiac failure, or respiratory paralysis.

Further, if the victim escapes the three possibilities of a fatal issue above mentioned, it may succumb to the effects of the pathological changes in the lungs and kidneys. This last risk is however, not a large one, except with dogs, and if the animal survives the nervous and circulatory depression, it usually recovers with wonderful rapidity.

IX.—Comparison of Experimental Results with the Symptoms of *Pseudechis* Poisoning in Man.

In comparing the results obtained by these experiments on animals, with the clinical symptoms manifested by patients bitten by this snake, the important fact which I have endeavoured to emphasise, viz.:—that the symptoms depend to a large extent upon the rapidity with which the venom reaches the circulation, must be carefully borne in mind. If this is remembered, I think it will be obvious that every observation from experiments on the lower animals has its counterpart among the symptoms of some cases of snake bite. Corpuscles are to some extent broken up, for I have myself found hæmoglobin in the urine. There are numerous records of cases where the urine has been stated to be bloody, but I am not aware that the reporter has taken the trouble to ascertain whether the colouration of the urine was due to hæmoglobin or to corpuscles. In the cases which I myself examined, there were no red cells at all, but only pigment. The positive phase of the effect of *Pseudechis* venom on the coagulability of the blood of animals, has been shown to be produced only when the venom reaches the circulation rapidly, as when intravenously introduced, or injected subcutaneously in large doses. In cases of snake bite in man, such conditions are very rarely satisfied, for the poison is usually deposited in the subcutaneous tissue and not directly into a vein, and in the former case is, relatively to the size of the victim, not sufficient in quantity to produce thrombosis. There exist, however, records of cases where the individual has died in less than half an hour, and in one of these cases there was a white (ante-mortem) clot found in the heart at the autopsy. In this case death was very possibly due to intravascular clotting. Although the conditions are unfavourable for the manifestation of a pronounced positive phase of coagulability which would occasion intravascular clotting, the after negative phase is always more or less present. It has long been known that the blood after death from the bite of this snake, clots only feebly, or else

remains permanently fluid, and Dr. Skinner of Beechworth,[1] has also recorded the fact that the coagulability of the blood appeared, during life, to be considerably diminished.

As regards the action upon the circulatory mechanism, experimental results are in accord with clinical observations. Faintness, feeble rapid pulse, with cold extremities, and blanched skin have been usually recorded. The description of the nervous symptoms coincides absolutely with the results of experiment. Thus the respiration is usually described as being at first slightly quickened, and then becoming progressively shallower. Sensation is blunted, and eventually stimulation of the nerves of special sense fail to evoke any reaction. The pupil is dilated, and insensible to light. The patient becomes comatose, and death generally occurs from failure of the respiration. All these symptoms occurred in those experiments on animals in which the conditions are at all comparable.

Furthermore, hæmorrhages from the kidneys, and from mucous tracts, are not uncommon in severe cases of bite from this snake, and are generally looked upon as very unfavourable symptoms. Experiments on animals show that the severity of these symptoms varies with the concentration with which the poison reaches the circulation. Albuminuria has been found when looked for, and has persisted for some few days after the apparent convalescence of the patient, so that it would appear as if the venom exerted the same pathological effect upon the kidneys in man, as upon those of the lower animals.

I am not aware of any record of symptoms of lung complication. Even in animals, the actual condition of these organs was not suspected until after death. The lungs have however been found after death from the bite of this snake to be the seat of hæmorrhages.

---

1 "Austr. Med. Gazette," March, 1893.

Appendix—The Toxic Value of Venoms.

Calmette[1] has worked out a table of the relative toxicity of venoms, as Roux and Vaillard have done for tetanus toxines, based on the number of grammes of an animal (rabbit) killed by one gramme of dry poison subcutaneously introduced. He found the toxic value calculated in this way was represented by the following numbers :

Cobra	4,000,000
Hoplocephalus curtus ...	3,450,000
Pseudechis	800,000
Pelias berus	250,000

My own experiments with rabbits place the toxic power of the two Australian venoms higher, viz.:—

Hoplocephalus curtus ...	4,000,000
Pseudechis	2,000,000

That is to say that ·00025 gramme of the former invariably kills a rabbit of 1 kilogramme weight, and ·0005 gramme of the latter is required to effect the same end. This is a very high virulence, and much exceeds that of most of the poisonous proteids of zymotic diseases hitherto separated, and is about the same as the diptheria toxine of Roux and Yersin.[2] I append the toxic values of albumoses from diptheria and anthrax toxine,[3] and toxo-peptone[4] from cholera cultures, calculated in the same way for comparison :

Diptheria toxine	4,000,000 (about)
Anthrax albumoses	80
Toxo-peptone	3,000

---

[1] Annal de l' Institut Pasteur, Tome. VIII., 1894.

[2] Quoted by Sims Woodhead—Bacteria and their Products, p. 307.

[3] Sydney Martin—" Reports of Local Government Board," 1890-91.

[4] Petri, quoted by Vaughan and Norry—" Ptomaines and Leucomaines" p. 169.

CONSIDERATIONS ON THE SURVIVING REFUGEES IN AUSTRAL LANDS OF ANCIENT ANTARCTIC LIFE.

By C. HEDLEY, F.L.S.,
Assistant in Zoology to the Australian Museum.

[*Read before the Royal Society of N. S. Wales, August 7, 1895.*]

To ordinary readers the most desolate region imaginable is that within the Arctic Circle. Yet the intrepid explorers who have furthest penetrated into the northern wilds, encountered there bears, wolves, musk oxen, walrus, seals and other mammals, and saw flocks of birds steering northwards beyond the utmost limit of discovery.

Infinitely more desolate is the mysterious and pehaps impenetrable Antarctic Continent or Archipelago. For aught we know, here may tower loftier mountains than geographers have marked in the Himalayas. From the ship's deck, voyagers[1] have descried volcanic peaks trending into an interior which extends as an unbroken sheet of ice and snow. Beyond the beach, its whole surface hardly now nourishes a single animal or plant. For the lichen reported by Borchgrevink[2] from Possession Island and Cape Adare alone constitutes the recorded terrestrial flora. Enveloped in an atmosphere of universal death, wrapped in its closely clinging cerements of ice and snow, the one expression of the Antarctica of to-day is that of lifeless silence.[3]

But it was once otherwise. Not only may a naturalist assert that here stately forests once stood, streams once rippled and green fields smiled, but he can picture what trees composed those

[1] M'Cormick—A sketch of the Antarctic Regions, embracing a few Remarks, Geographical and Ornithological.—The Tasmanian Journal of Natural Science, I., p. 246.

[2] The Geographical Journal, Vol. v., June 1895, p. 583.

[3] For the best physical and geographical description of Antarctica see Murray—The Geographical Journal, Vol. III., pp. 1 - 27.

forests, of what kind were the frogs and snails they sheltered, and of what form were the fish that swam in those streams.

Early scientific travellers[1] remarked that the converging continental masses of the southern world held as common stock certain forms of life. Closer enquiry elicited that these common forms were primitive, often isolated types, survivors of some ancient population overwhelmed and slaughtered by invaders from the north. South Africa was found to stand somewhat apart from the closer bond which united Tasmania and Australia to New Zealand and South America, while New Zealand is in turn poorer actually, if not comparatively, than Tasmania in South American affinities.

"Community of type," writes Dr. Gill,[2] "must be the expression of community of origin . . . and recent palæontological finds indicate that even the Thylacinids (or at least forms resembling them) were formerly natives of southern America . . . The freshwater fishes [of New Zealand] must have been derived from the same common source as those of the isothermal portions of Australia (of course including Tasmania), and southern America. There may not have been a continuity of land at any one time between South America, Australia, and New Zealand, but, at some remote period in the past, it is at least possible that there was a region in which Galaxids and Haplochitonids were developed, and subsequently representatives of those families might have found their way into the regions where they now abound."

An enumeration of the genera common to South America, New Zealand and Tasmania, and therefore probably of Antarctic origin would exceed the limits of this paper. Forbes[3] quotes numerous instances, and for more exhaustive data monographs of most

---

[1] J. D. Hooker, on the Huon Pine, &c.—London Journal of Botany, Vol. IV., 1845, pp. 137 – 157.

[2] A comparison of Antipodal Faunas—National Academy of Sciences, Vol. VI., p. 108.

[3] Antarctica, a supposed former Southern Continent—Natural Science III., pp. 54 – 57.

groups of animals and plants of these countries may be consulted.[1]

We may compare the shattered biological monuments of Tasmania and South America to the broken columns found by Oriental travellers in the ruined and deserted cities of a vanished civilisation. And as an archæologist may restore from such fragments the fallen temples or disused acqueducts, so may a naturalist trace the missing arches of life that once spanned the gap. Some of the efforts to do so may be here reviewed.

Prof. Hutton has conjectured[2] that such a bridge spanned the South Pacific from Chili to Samoa and thence to New Zealand. Claiming South American relations for the New Zealand fauna and flora, he accounts for their entry into New Zealand by this assumed bridge. Against Prof. Hutton's arguments it may be urged that though the relation of New Zealand to South America is indisputable, it is less than between the latter and Tasmania; and that the demand for a former union may be satisfied by supposing an approach but not a connection with Antarctica.

---

1 For fungi see Darwin, Voy. Beagle, p. 236; mosses, Mueller, Trans. N.Z. Inst., xxv., p. 428: grasses, Buchanan, Indigenous Grasses of New Zealand; trees, Kirk, the Forest Flora of New Zealand; lichens, Shirley, Proc. Roy. Soc. Queensland, Vol. x., p. 54; earthworms, Beddard, A Textbook of Zoogeography, p. 60; isopods, the same, p. 173; crayfish, Parker, N. Z. Inst., xix., p. 154; fluviatile mollusca, Hedley, P.L.S., N.S.W., (2) viii., p. 507, and ix., p. 464; trematodes, Haswell, A Monograph of the Temnocephalæ, Macleay Memorial Volume; ants, Emery, Nature, Aug. 22, 1895, p. 400; planarians, Dendy, Trans. New Zealand Inst., 1895, p. 177; diptera, Skuse, Proc. Austr. Assoc. Ad. Science, i., pp. 526–540 and Osten Sacken, Berliner Entomolog. Zeit., Bd. xxx., 1886, Heft ii., pp. 153–187; lepidoptera, Meyrick, various papers, Trans. New Zealand Institute. Mr. Skuse has drawn my attention to the interesting South American and Australian distribution of *Stigmodera* and other genera grouped around it, as enumerated in Gemminger and Harold's Catalogus Coleopterorum, Tome v., pp. 1392–1405. When defects in the current classification of invertebrates are amended, the likeness between southern faunas will grow more apparent.

2 On the Origin of the Fauna and Flora of New Zealand—New Zealand Journal of Science, ii., pp. 1–249; and Ann. Mag. N.H., (5) xiii., p. 426.

The sole supports of the theoretical transpacific bridge are the difficulties it is believed to explain. A biologist might object, that *had such a bridge existed, New Zealand being at the furthest extremity, ought to contain fewer South American affinities than do intermediate Polynesian islands*, like Samoa or Tahiti, lying nearer to the source. On the contrary, these islands are devoid of such. And a geologist might say that this supposed bridge was discordant with the main orographic structure of the region. Its relics are detected by Prof. Hutton in an abyssal area two thousand fathoms deep, which only in strained language can be termed a "plateau." Of where he supposes that it lay, Geikie[1] writes, "so abruptly does the continental plateau rise from the ocean trough, that a depression of the sea level, or an elevation of the plateau for ten thousand feet would add only a narrow belt to the Pacific coast between Alaska and Cape Horn." Much of the biological and geological data, on which Prof. Hutton's paper was based, have since been refuted or withdrawn.

Another answer to the question at issue is tendered by Dr. H. O. Forbes.[2] After a lucid summary of the kinship of austral life observed by earlier naturalists, and of facts collected by himself in the Chatham Islands, he constructs an immense hypothetical Antarctic Continent to explain these problems.

The impression left on my mind by a careful study of this paper is that a foundation so slender is insufficient to bear a superstructure so vast. No geological era is assigned for the map of Ancient Antarctica accompanying the article. To this area the Mascarene Islands appear to be attached chiefly upon the strength of an extinct bird of dubious lineage. The difficulties of the change from the climate of primeval Antarctica and the change in the depth of circumpolar seas are not explained, or indeed the changes proved. The Antarctic fauna and flora, so far as surviving fragments allow us to reconstruct them, do not suggest that wealth

[1] Address Geograph. Sect. British Association, 1892, p. 796.

[2] The Chatham Islands, their relation to a former southern continent, Vol. III., Supplementary Papers, Royal Geographical Society, 1893.

of forms which so wide an extent of land should have developed. A much harsher climate would have prevailed over Forbes' broad continental area than over a chain of islands or a narrow strip of land. *Had the conditions indicated by Dr. Forbes once existed, then each of the southern land masses should have preserved an equal heritage of Antarctic life*, which is not the case. A sharing of population may not be invariably cited (as it is in this paper) as indicative of former land passages, for it has been clearly demonstrated in the case of the Azores and Galapagos that considerable immigration may occur across wide expanses of ocean.

Mr. H. A. Pilsbry has remarked,[1] that "the presence of very similar forms in southern South America and Tasmania and New Zealand, has been accounted for by the hypothesis of a former more extensive Austral continent or "Antarctica," which may have been supplied with these snails, as well as with certain marsupials, fishes, &c. from Australia, and subsequently became united at Cape Horn, transferring the fauna. The connection could hardly have been in reverse order, or why should not Edentates and Hystricomorph Rodents have invaded Australia."

The opposite view, viz. that Antarctica transferred a fauna from America to Australia is favoured by the facts that the fossil marsupials from the Patagonian Eocene antedate[2] any fossil

[1] Guide to the Study of Helices, p. xxxix., Philadelphia 1895.

[2] This statement is derived from the following data, for which I am chiefly indebted to the kindness of my friend Mr. W. S. Dun, Assistant Palæontologist to the Geological Survey of N.S.W., himself the author of important papers on the subject. The oldest DESCRIBED Australian mammalia are Pliocene; viz. *Ornithorhyncus maximus*, Dun, and *Echidna robusta*, Dun, (Records Geol. Survey, N.S.W., IV., p. 119) from this Colony. From Victoria Prof. McCoy has claimed as Pliocene (Prodromus, Palæontology of Victoria, Decades I. - VII.) *Phascolomys plocenius*, McCoy, *Diprotodon longiceps*, McCoy, *Macropus titan*, Owen, and *Procoptodon goliah*, Owen. Some bones recognised by Johnston (Geol. Tasmania, p. 261) and Tate (Proc. Roy. Soc. N.S.W., 1893, p. 168) as *Halmaturus* from the Eocene of Table Cape, Tasmania, can hardly be discussed till they have been studied, described and named. Yet on *a priori* grounds the Diprotodontia can scarcely be supposed to have so far proceeded on the path of differentiation from the radical Polyprotodont stock as to have evolved into *Halmaturus* at the early date of the Eocene; further, the sea shells of this deposit form an incongruous environment for a wallaby. For a list of the numerous marsupials extracted from the Upper Eocene beds of Santa Cruz, South America, see Zittel, Geol. Mag., x., p. 456.

marsupials recorded from Australia, that the marsupialia dawn upon the Australian horizon as a highly differentiated group, and that Prof. Spencer has demonstrated[1] "that the diprotodonts had their origin in the Euronotian region," meaning that their centre of dispersal lay to the south east of Australia. Von Ihering has suggested[2] that a large area of South America was separated in Mesozoic times from the remainder and maintained a distinct fauna and flora. If from this tract, which he terms Archiplata, were excluded, as he holds, placental mammals, it may have peopled Australia with marsupials and yet not have transferred thence Edentates or Hystricomorph Rodents.

The relation of Antarctica to African lands is a subject on which an Australian student has little chance to form an opinion. Perhaps the faint though real affinity (as shown in the distribution of the molluscs Endodontidæ, Rhytididæ, and Acavinæ), would be explicable on the supposition that before either America or Australia had united with Antarctica, Africa had already been joined to and broken from it, receiving a colony thence or leaving one there to mix with American and Australian forms when the vicissitudes of continental growth permitted.

In an inquiry[3] into the distribution of the pond snail *Gundlachia* I lately proposed as the simplest solution of the problem. That DURING THE MESOZOIC OR OLDER TERTIARY, A STRIP OF LAND WITH A MILD CLIMATE EXTENDED ACROSS THE SOUTH POLE FROM TASMANIA TO TERRA DEL FUEGO, AND THAT TERTIARY NEW ZEALAND THEN REACHED SUFFICIENTLY NEAR TO THIS ANTARCTIC LAND, WITHOUT JOINING IT, TO RECEIVE BY FLIGHT OR DRIFT MANY PLANTS AND ANIMALS, as the Galapagos received their population from America, or the Azores theirs from Europe.

This conclusion was built upon the following evidence. A minimum of land extension, compared with that asked for by Hutton or Forbes, was demanded. A milder climate is admitted by

---

[2] Report Austr. Assoc. Adv. Science, 1892, p. 118.
[3] Trans. New Zealand Institute, 1891, xxiv., p. 434.
[1] Proc. Linn. Soc. N.S.W., (2) viii., p. 508.

geologists, even by those who dispute its cause, to have formerly prevailed in Arctic regions; a mild Antarctic climate should therefore be admissible. Dr. Murray remarks[1] of the fossils collected by Capt. Jensen, close to the Antarctic Circle, that they "are probably of a Lower Tertiary age, and they indicate a warmer temperature than now prevails in these high southern latitudes." A cursory survey of a collection of Eocene Mollusca from the Muddy Creek beds of Victoria, suggests to me that warmer seas then prevailed. Its wealth of *Cypræa* and *Voluta* point to a tropical climate. I observe there tubes of *Kuphus*, a genus now ranging from Sumatra to the Solomons, whose evidence is corroborated by extinct allies of *Nautilus*. That New Zealand once extended very far south of its present position to or perhaps beyond the Macquarie Islands, is granted by all who have investigated the subject.[2] Possibly this southward extension was synchronous with the northward extension indicated[3] by the range of *Placostylus*. That this southward extension of New Zealand did not, during the marsupial exodus, actually touch the highway between Tasmania and South America, I infer from the fact that such passengers as the venomous snakes, extinct *Palimnarchus*, cystignathous frogs, monotremes and marsupials, failed to arrive in New Zealand. The southward prolongation of Tasmania in the direction of Royal Company Island is suggested by the Tasmanian axes described[4] by Prof. David.

The evidence collected tends to show Antarctica as an unstable area, at one time dissolving into an archipelago, at another resolving itself into a continent.

How this would affect the marine shallow water fauna has not been previously considered. Under the circumstances I have

---

[1] Notes on an important Geographical Discovery in the Antarctic Regions—Scottish Geographical Magazine, Vol. x., p. 195.

[2] Vide Blanchard, Comptes Rendus, 1882, p. 386.

[3] Proc. Linn. Soc. N.S.W., (2) VII., p. 335.

[4] Presidential Addresses, Proc. Linn. Soc. N.S.W., (2) VIII., p. 606, and Vol. X., p. 155.

described, the South Pacific would stretch within a few degrees of the Pole into a deep bight or gulf extending from Tasmania to Cape Horn. Into the western extremity would open the long and narrow tongue of what is now the Tasman Sea. When the climate cooled, the fauna at the head of this Antarctic Gulf, as I propose to call it, would be driven northwards to milder zones. By diverging meridians a similar fauna would reach New Zealand, New South Wales and Chili.[1] In a precisely similar manner, Darwin[2] has shown how the northern Glacial period drove the same Polar flora by radiating paths to the Alps, Himalayas and Alleghanies, where they now survive stranded on mountain tops.

If, when this northward migration occurred, continuous land had reached from Australia to Chili, then none of the fauna of the Antarctic Gulf could have entered either the Indian or the South Atlantic Oceans. We have, however, no warrant for believing that the Antarctic bridge long endured as continuous and contemporaneous land; and that it was pierced by channels is proved by the escape of stray members of that characteristically Antarctic genus *Struthiolaria* to Patagonian coasts (*S. ornata*, Sowerby)[3] on the one hand, and to Kerguelen (*S. mirabilis*, Smith)[4] on the other.

The destruction[5] which the ancient fauna of the Antarctic Gulf has endured and the length of time which has elapsed since its expulsion, deprives us of much hope of reconstructing it. Since that event, for instance, the genus *Haliotis* has probably altogether grown up as a characteristic feature of the modern Australian

---

[1] *Cf.* The occurrence of *Concholepas*, recent only in South America, as a fossil in Australia.—These Proceedings, ante, 1893, p. 171.

[2] Origin of Species, Chap. XI.

[3] Darwin, Geol. Obs. S. America, pp. 376, 618, pl. iv., f. 62.

[4] Trans. Roy. Soc., Vol. CLXVIII., p. 170, pl. ix., f. 3.

[5] "We seem [in the Pliocene] to be dealing with the remains of an earlier fauna disappearing rapidly before the conquering host of the recent fauna which had invaded New Zealand some time previously."—Hutton, Macleay Memorial Vol., p. 36.

molluscan fauna. A search among the more persistent of living types may produce some torn pages of its history. One such is recognised by the writer in *Lucapinella*, whose occurrence in Australian waters is noted.[1] But palæontology must be chiefly called on to relate the story of the decline and fall of the Antarctic marine fauna.

ICEBERGS IN THE SOUTHERN OCEAN.

By H. C. Russell, B.A., C.M.G., F.R.S., &c.

[With Plate XII.]

[*Read before the Royal Society of N. S. Wales, September 4, 1895.*]

I have prepared this short paper upon icebergs, not because I consider myself an expert on the subject, but because I entirely agree with Lieutenant Maury, a great authority, when he said that "a sudden accession of icebergs is a danger to navigation." We have had within the last two years, or rather eighteen months, an extraordinary accession of icebergs between the Cape of Good Hope and Australia, and the danger caused by innumerable icebergs in these waters is so real that the publication of the facts cannot be delayed.

The literature known to me on the subject of icebergs in relation to navigation is not very extensive, and very little is said about it in the ordinary books of reference, and some of that little would have been inaccessible to me but for the aid of Captain Bedford, Examiner to the Marine Board, who has very kindly lent me a book that covers a greater part of the ground, seeing that it has discussed every record of icebergs in the southern ocean from the time of Captain Cook to 1858. It is called a paper on "Icebergs

---

[1] Proc. Roy. Soc., Vict., 1894, p. 197.

in the Southern Ocean," prepared by John Thomas Towson, F.R.G.S., and was published by the Board of Trade and Admiralty, London. But for the period intervening between 1858 and my own work, I find very little in print. Mr. Towson claims to have selected the well-known ocean tracks for vessels coming to Australia in 1848, and he adds that for six years thereafter there were no complaints of icebergs as a danger in the tracks he had laid down, until the latter part of 1854, when alarming accounts of ice in the southern ocean began to come in. In November, both in the outward and homeward tracks, more particularly between Cape Horn and Cape of Good Hope, many icebergs were seen; and writing in 1858 he goes on to say, "Since April, 1855, however, the only reports of icebergs sighted in this part of the ocean are much farther south and confined to a small area."

Noticing the frequent reports of icebergs recently I began to collect them, and found in the *Australian Shipping News* of August 5, 1893, two articles on icebergs, one copied from the *Nautical Magazine*, the other from the *Sydney Morning Herald*. The *Nautical Magazine* says, "Since November, 1891, reports of ice in the southern ocean have been very frequent."

In addition to these, I have collected all the reports from the daily press, and record here my obligations to the following gentlemen who have very kindly furnished me with detailed reports of icebergs:—Mr. R. Woodget, master of the ship "Cutty Sark," Nos. 69 and 70 on list; Mr. Charles Dixon, master of the ship "Erin's Isle," No. 103; Mr. T. Messenger, master of the barque "Ladas," No. 89; Commander Burgess, R.N.R., sub-lieutenant s.s. "Bungaree," No. 82; Mr. Thomas J. Cook, master of the ship "Oronsay," No. 102.

The reports detailed in subsequent pages prove, I think, that there has been of late another remarkable outburst of icebergs in parts of the ocean where they are very dangerous to navigation.

Many years since, Lieutenant Maury studied this subject and condensed what he learned into the statement, "We can only say

that to the north of latitude 50°, Antarctic icebergs most abound between the meridians 15° west and 55° east. Mr. Towson, after an elaborate study, repeats the statement, but alters the limits to 50° west to 10° east; and the result of my own work would make these limits 50° west and 110° east. This, in itself, shews the greater area now affected and the necessity for some one to take the matter up. (See *Plate* 12).

It is, I think, evident that for a convenient study of these records, one must have a chart, and I have marked each record in the same way, viz., by a small circle on the ship's position at the time, each circle is marked with lines which shew the the date. Thus: a circle with one vertical bar is for 1891; two bars, 1892; three bars, one being across, 1893; four bars crossed, 1894; and a circle with a V in it, 1895; for 1888 a circle alone is used. The convenience of this is at once obvious when we come to use it. Each record also has a number, by means of which the original report can be found in the letterpress.

I have had put on the chart another remarkable record—the track of the abandoned ship "Dumbartonshire." This extends from longitude 48° west to 14° 20′ east, nearly the whole of it being in latitude 40° The starting-point is in the iceberg region, and her progress therefore is the best possible guide to the direction and rate of motion of the icebergs.

The several positions of the derelict are marked on the chart by circles a little larger than the iceberg circles. The centre of the ring has been in each case placed as nearly as possible over the position in which she was seen, and these have been joined by a thick line. The derelict shews a very decided current from a region crowded by icebergs in 1892, nearly due east. If the icebergs followed the same course, their position in subsequent years about the Cape of Good Hope and thence towards Australia would be fully accounted for.

AS TO THE LOCALITIES OF THE ICEBERGS.

It will be seen on the chart that a very large group of icebergs, found soon after passing Cape Horn northwards, are nearly all

marked 1893, and the next group going northerly are marked 1892. At first sight this would look as if the icebergs had gone southerly against the current, but that view is obviously improbable, for they must go with—not against—the current. I think the relative positions would be satisfactorily accounted for thus: The 1892 lot, being right in the fairway of vessels taking the usual track round the Horn, would be avoided as soon as they were reported, and ships would shape a course nearer the main land in 1893 and find the icebergs recorded of that date. Meantime the whole lot were drifting eastward, like the "Dumbartonshire," and left a clear course near the Horn for homeward-bound ships, and hence, so far as I can learn, no icebergs are recorded there in 1894 and 1895.

From 1891 onwards, however, vessels bound for Australia viâ the Cape of Good Hope found icebergs east of the Cape. At first a few were seen, and the number has gradually increased, until now (July 26th, 1895) the chart is fairly strewn with record spots from the Cape to the longitude of Perth, and from 40° to 48° south, 1895 having far the greater number to its credit. As a whole they are more to the east than those of the preceding years; and in considering their numbers, it is necessary to remember that it is not one iceberg but one position of the ship that is marked on the chart, and that in almost every instance great numbers of icebergs were seen. Many of the ships saw forty or fifty a day, and others still more and up to one hundred and fifty.

I do not mean to assert that all these icebergs drifted over from the lee of Patagonia, but that many of them did do so I think there can be no doubt, in view of the very strong evidence of easterly drift which we find in the derelict "Dumbartonshire."

Fitzroy's[1] experience also favours this view, for he says:—"Immediately round Cape Horn and the Falkland Islands ice seldom remains, as any that is drifted there is carried eastward

[1] "Weather," 1862, p. 149, and Maury, p. 467.

by the current that always sets around the great southern promontory, and the south-easterly winds help this."

From what little is known about the currents concerned in transferring these icebergs, one would expect that such groups as those of 1892 and 1893 under Patagonia would, when they began to go eastward, separate and draw into lines as we find them in 1894 and 1895, because the current is more rapid from latitude 30° southwards, and therefore the most southerly icebergs would travel fastest and also have fewer miles in a degree; and we cannot overlook the effect of the wind, which would necessarily be greater on icebergs presenting large flat surfaces than on those presenting sloping sides. Simply as evidence on this point, it is to be hoped that the "Dumbartonshire" will be sighted again.

Although the evidence of easterly drift appears to me to be so strong, I do not mean to assert that all the icebergs seen recently between the Cape and Australia came from the icefields under the lee of Patagonia. The experience of the master of the "Ladas" barque, bound from South America to Australia, shews that in latitude 50° to 53° he passed enormous fields of ice, and after passing the prime meridian they became so thick that he had to work northwards to avoid them, and it is more than probable that some of these made northing and joined the others drifting eastward.

Reference has already been made to the unusual position of icebergs between latitudes 40° and 50°. Maury, as we have seen, made the easterly limit 55°, Towson made it 10° east: the reports now under discussion make it 110° east.

Similar, but not so great uncertainty as to the extent of ice seems to attach to the area between New Zealand and Cape Horn. Admiral Fitzroy[1] says:—"In the South Pacific, between 150° and 100° west longitude, and 50° to 60° latitude, every ship that risks a passage through it finds numerous and some enormous masses of ice. Immense islands rather than icebergs have been

1 "Weather," p. 160.

passed thereabouts, eight hundred to one thousand feet above the sea and several miles in circumference." And Towson[1] says :— "On the homeward passage to the meridian of 80° west, a great number of icebergs are met with in the lower rather than in the higher latitudes. But from June to December inclusive, the parallel of 57° south should be preferred, since in most cases those who have adopted the higher parallel have been impeded or endangered by pack ice."

It will be seen in the accompanying chart that the limits of this icefield in 1891 to 1895 was different from either of those mentioned above, and lies between 172° and 109° west.

I find no record of icebergs to the east of New Zealand by Maury, Fitzroy, or Towson, and yet they form in this outburst a conspicuous feature about the Chatham Islands.

Lieutenant Maury, as we have seen, refers to a sudden accession of icebergs, and Towson does the same, while we have now the evidence of a third and more extensive outburst ; but, so far, I have found nothing to indicate a repetition in regular periods, and if the views expressed later as to the cause of the increase in numbers is correct, there is no reason to suppose that these periods should recur at regular intervals.

The discussion of the records on which this paper has been written, brings before us such untold numbers of icebergs, that it is difficult to believe that they have taken so many thousands of years to form as some authorities demand.[2] Vast as the Antarctic continent is, it does not seem possible that room could be found on it for the building up gradually from pre-adamite times all these multitudes of icebergs. When we trace them in the ocean, it is evident that they drift northwards, get into warmer water, where they begin to break up with tremendous noise (see List No. 70) and grinding, which, aided by the solvent power of the water, destroys the iceberg in a comparatively short time. How then can they have taken so many thousands of years

[1] Towson, "Icebergs in the Southern Ocean," p. 7. [2] Ibid. (Note) p. 3.

to make as some authorities demand? Were the Antarctic regions as large as the whole world, there would not be space to make the icebergs which we see in process of destruction in the ocean, if the origin of each iceberg was away back in pre-adamite days.

When we come to look at these reports closely, we find the great majority of the icebergs are of moderate dimensions—five hundred to two thousand feet in extreme dimensions—and such icebergs might, I think, be formed in comparatively short periods. Slow as the motion of solid ice is known to be, it does make a measurable progress from year to year; that progress depending upon the amount of snow, and the decline down which it is finding its way to the sea. But taking an average glacier, it progresses a mile in from twenty to thirty years, and therefore the great majority of icebergs of the dimensions just given could be made in comparatively short periods. Some are, however, very much larger, and the number of icebergs seem to be vastly greater in some years than in others. As an explanation of this it has been suggested that unusual falls of snow may account for it by accelerating the motion of the ice; but I think the circumstances forbid the acceptance of this view, because the motion of the glacier, as we have already seen, depends mainly on the declivity down which it is descending, and that does not alter, and the piling up of snow could not in one year cause such a marked increase in the rate of flow as would be necessary to account for the enormous increase in number of icebergs which appear from time to time, as for instance in 1854 and 1891.

There must evidently be a force sufficient to break off the icebergs which are slowly forming on shore, and to do it at irregular periods separated by many years. Such a force seems to reside in the volcanoes of the Antarctic continent, when they burst forth in eruption and earthquake, and so shake the foreshores, that the icebergs are broken off from the glaciers and set adrift to float we know not where.

This view derives some support from the character of the icebergs when outbursts occur, as at the end of 1854, and again recently, for on each occasion there were great icebergs which only some convulsion of nature could set adrift. One of these was reported by twenty-one ships in 1855. It was a solid mass of ice, measuring sixty miles on one side, forty miles on another, and in the third side (for it was triangular), there was a great bay, into which three vessels unconsciously sailed—two got out by tremendous exertion, and the third became a total wreck.

Again, on January 17, 1893 (see No. 57 in List), the ship "Loch Torridon," in latitude 53° 51′, longitude 46° west, sailed for fifty miles along one side of an immense ice island, and the captain saw another estimated to be one thousand five hundred feet high. Again (No. 55 in List) on January 11, 1893, the ships "Wasdale" and "Strathcathro" sailed all unconscious of danger into a horse-shoe shaped bay in an iceberg; it was twenty miles deep, ten miles across in the middle, and four miles wide at the entrance. The similarity of this ice-bound bay with the one seen in 1855, and another seen by Dampier in his voyages, is noteworthy, for they were all alike. It would seem as if there were some forming place, or mould, in which these icebergs are built up and held until some great eruption sets them free.

If we accept the suggestion of the cause of sudden accessions of icebergs here put forward, we have a cause known to be in operation there, and quite sufficient to account for the enormous number of icebergs, and also of the large dimensions of some of them at these times of outburst.

I have endeavoured to prepare the chart of reported icebergs so that it should be easily read. The locality of every report is marked on the chart by a circle, the year in which the ice was seen is shewn by the number of bars within the circle, a number is added so that the report can be found in the following list and all particulars obtained. The positions in which the derelict "Dumbartonshire" was seen, are marked in the same way, and

all particulars about her are given here. In cases where ice has been seen day after day, the fact is indicated by a series of circles all having the same year and number.

NOTE.—Captain T. Messenger, in his MS., remarks that his barometer frequently rose rapidly when nearing any vast quantity of ice; the thermometer remaining steady. See No. 89.

THE DERELICT "DUMBARTONSHIRE."

The "Dumbartonshire" was loaded with nitrate from the west coast of South America. After having been dismasted in a heavy gale, she was abandoned by her crew in August, 1894 (the day is not given) in latitude 40° south and longitude 40° east. She was next seen by Captain Prask, of the "Port Douglas," about January 18, 1895 (day not given), in latitude 40° south and 5° west. Assuming the date of abandonment to be August 15, we have above an interval of one hundred and fifty-five days, during which the ship drifted one thousand eight hundred and fifty miles, which is at the rate of twelve miles per day. The derelict was next reported by Mr. William McFarlane, master of the "East Lothian," who, in a letter to me on the subject, says: "At 5 a.m. January 27, 1895, I passed a derelict of about one thousand tons register; her mizzen-mast was standing. I hauled the "East Lothian" as close to the derelict as was prudent, but I saw no life on board of her. The position of the derelict was 40° 30′ south, longitude 2° 20′ east; this position was verified at 8 a.m. and at noon." Progress in nine days, three hundred and eighty-nine miles, or forty-three miles per day, rate probably due to a gale of wind. The "Dumbartonshire" was next seen by the master of the barque "Brenhilda," on March 7, 1895, in latitude 40° 53′ south, and longitude 14° 12′ east. The interval in miles here is six hundred and thirty in thirty-nine days, or sixteen miles per day. These are the only reports about the "Dumbartonshire" that have reached me.

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
1	Nov. 14, 1891	Dunsyre	43 S.	17 E.	Sighted icebergs.
2	Nov. 30, 1891	Gainsborough ...	45 S.	9 E.	Saw apparently the same icebergs as No. 1.
3	Dec. 8, 1891	Winifred	44 S.	14 E.	Surrounded by icebergs four hundred feet high.
4	Dec 12, 1891	Semiramis	44 S.	10 E.	Passed icebergs.
5	Dec. 12, 1891	Magnet	44 S.	10 E.	Passed icebergs.
6	Dec. 14, 1891	City of York... ...	48 S.	103 – 108 E.	Reported icebergs.
7	Dec., 1891 ...	Coptic	48 S.	103 – 108 E.	Reported icebergs.
8	Dec., 1891 ...	... ...	...	...	Various ships arriving at Australian ports from England reported icebergs off the Cape of Good Hope.
9	Feb. 4 – 9, /92	Fifeshire	57 – 59 S.	147 – 109 W.	Passed many icebergs.
				36 W	Stood into a wide opening between two icy cliffs three hundred feet high; this passage proved to be the entrance to a horse-shoe shaped bay, formed in an immense ice island. Ship had to beat out again. One iceberg was not less than one thousand feet high.
10	April 6, 1892	Cromdale	46 S.		
				50 W.	Many icebergs passed.
11	April 21, 1892	Valdivia	50 S.	35 W.	Very large iceberg close alongside in early morning.
	April 24, 1892	,, ...	43 S.		Eighty-five in sight during the next eight hours.
				31 W.	Passed the last ice.
	April 27, 1892	,, ...	39 S.	38 W.	Collided with iceberg, hundreds in the vicinity.
12	April 23, 1892	Duntrune	47 S.	25 W.	Surrounded by icebergs, one at least one thousand feet high; another, eight hundred to one thousand feet high, was sailed along for forty miles.
13	May, 1892 ...	Strathdon	45 S.		
				37, 35 W.	Sighted more than one hundred icebergs.
14	May 10, 1892	Invercargill	45, 43 S.	39 W.	Passed iceberg four hundred feet high; another was brown and black, looking exactly like an island.
15	May 18, 1892	Hesperus	44 S.		
				34 W.	Hemmed in by ice on every hand.
16	May, 1892 ...	Loch Torridon ...	45 S.		

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
17	May 20, 1892	Neotsfield	46 S.	38 W.	In the midst of many icebergs about four hundred feet high, and only a small channel about a mile wide visible through which she sailed, and for seventy miles not a break could be seen to the north-west and very few openings to the south-east.
	May 22, 1892	„	42 S.	39 W.	Last iceberg seen.
18	June 2, 1892	County of Edinburgh	45 S.	37 W.	Passed numerous icebergs, ranging from two hundred to nine hundred feet in height over a path one hundred miles long.
19	June 10, 1892	Eden Holme... ...	position not given		Passed many icebergs two hundred feet high, massed in the shape of a crescent; one, evidently recently turned over, was of a dark green with brown or dark red patches.
20	June 11, 1892	J. W. Burmester ...	44 S.	38 W.	Sighted huge iceberg, very dangerous to navigation.
21	June 16, 1892	Clan Grant	44 S.	38 W.	Saw several very large icebergs, and others just awash.
22	June 18, 1892	Lady Palmerston ...	somewhat to S.E. of Falkland Islands		Saw two large icebergs about two miles in length.
	June 20 – 24	„ ...			Sailed through an immense number of icebergs, extending one hundred and eighty miles from south to north, and one hundred and sixty miles from east to west; on the 22nd she was fairly walled up.
23	June 17, 1892	Stanmore	45 S.	39 W.	Passed three large icebergs, next day was found to be encircled by icebergs; sixty large icebergs were left behind in twenty-four hours, some of which were five miles long and almost flush with the water.
24	June 18, 1892	Alice	44 S.	33 W.	Passed an iceberg four hundred feet high, next day sailed along a solid body of ice for thirty-five miles of not less than three hundred icebergs.
	June 20, 1892	„	...	...	Sailed forty miles along one side of a solid mass of ice from twenty to four hundred feet in height.

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
25	June 18, 1892	Roland	42 S.	31 W.	Passed over one hundred icebergs close together, and some of these were two or three miles long.
26	June 20, 1892	Parsee	45 S.	31 W.	Sighted an iceberg, at first mistaken for an unknown island, much blackened and apparently very thickly coated with earthy matter and stones.
	June 21, 1892	„	41 S.	35 W.	Sailed forty miles along one side of a compact mass of icebergs of considerable individual size and extent.
27	June 26, 1892	Gladys	...	...	Passed two islands and some very long kelp, it is likely that these vigias were not land but enormous masses of ice; made out with difficulty.
	July 1, 1892	„	43 S.	33 W.	Completely embayed by icebergs.
	July 4, 1892	„	40 S.	32 W.	Did not get clear of ice until this date.
28	July 21, 1892	Lady Cairns... ...	52 S.	46 W.	Sighted two very large icebergs, while sea all around was covered with smaller pieces and drift ice.
	July 25, 1892	„	40 S.	34 W.	Last ice seen.
29	July 28, 1892	Kinfauns	42 S.	33 W.	Passed two icebergs four hundred feet high and three miles long.
	July 29, 1892	„	...	...	Ice on every hand, some of the bergs five hundred feet high and twelve miles long.
	July 31, 1822	„	39 S.	29 W.	Continuous chain of tremendous icebergs trending from north to south-west without an opening.
	Aug. 1, 1892	„	...	...	Surrounded by icebergs varying from two to six hundred feet in height and from two to three miles in length; passed at least a hundred during the forenoon, some level with the sea surface and very dangerous in thick weather; sailed four hundred miles in the presence of ice; the temperature was remarkably warm with the air temperature ranging from 44° to 54° and the water

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
					about 3° lower.
		Kinfauns	38 S.	27 W.	The last iceberg was seen.
30	Aug. 7, 1892	Euphrates	38 S.	31 W.	Fell in with first iceberg.
	Aug. 8, 1892	„	39 S.	29 W.	Fifty icebergs were seen varying in height from three to three hundred feet; low ones considered most dangerous
	Aug. 11, 1892		40 S.	18 W.	Passed last ice.
31	Aug. 8, 1892	Oriana	37 S.	27 W.	Sighted much ice, eight icebergs above the horizon at the same time, the largest about one hundred and thirty feet high and two miles in circumference.
32	Aug. 23, 1892	Pass of Balmaha ...	50 S.	39 E.	Sighted an iceberg right ahead.
	Aug. 28, 1892	„ ...	44 S.	34 W.	Stray masses passed up to this day when icebergs were all around, ninety-six icebergs counted from the deck, some being two hundred and fifty feet high and two miles long; an impenetrable icy barrier appeared ahead, so she was kept before the wind for half an hour till a passage was observed under the lee of a large iceberg. This proved dangerous, nothing ahead but ice as far as the eye could see from aloft, ship kept moving through a number of intricate passages. The icebergs seemed in every state of decay, some tabular wall faced cliffs, others obelisks, towers and arches. In the early morning the temperature of air and sea were 42°, but at 10 a.m. in the thick of the ice the water was 38° and the air 52°.
		„ ...	39 S.	...	Last ice seen, longitude not given.
33	Aug. 30, 1892	Bay of Naples ...	57 S.	60 W.	Sighted an iceberg one hundred and fifty feet high and one mile long.
	Sept. 5, 1892	„ ...	53 S.	46 W.	Sighted another, three hundred feet high and five miles long.

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
34	Sept. 13, 1892	Kilbrannon	49 S.	176 W.	Passed icebergs, some four hundred feet high and one mile long on the water line ; temperature of water through the night 44° and the air 42°.
	Sept. 14, 1892	„	47 S.	179 W.	A number of icebergs hove in sight, and an ice island varying in height from fifty to four hundred feet, with a side of five miles ; saw about thirty icebergs in all. Temperature of sea 42° to 44° and the air about 2° less.
35	Sept. 25, 1892	City of Glasgow ...	46 S.	179 W.	Passed thirteen large icebergs.
36	Sept. 28, 1892	Galgate	48 S.	42 W.	Met numerous icebergs in the South Atlantic on Sept. 28, one two hundred and fifty feet high, and two miles long, and next day another of similar dimensions.
	Oct. 1, 1892	„	48 S.	35 W.	Sailed between two large icebergs on Oct. 1st, and next day steered through an archipelago of icebergs two to three hundred feet in height and three hundred and fifty to three thousand feet long.
	Oct. 6, 1892	„	42 S.	27 W.	Passed quite four hundred icebergs, many dark but majority pure white, twenty-six large icebergs counted at one time. Temperature of water very little affected even when a cable length from an iceberg ; air temperature kept generally about 2° above that of the sea which was for many days of a green colour.
37	Oct. 1, 1892	Æolus	49 S.	44 W.	Sighted an iceberg three hundred feet high and two miles long.
	Oct. 4 – 8, 92	„	44 – 40 S.	31 – 26 W.	Passed innumerable like dangers from the 4th to 8th.
38	Oct. 1, 1892	Roderick Dhu ...	49 S.	43 W.	Passed an iceberg three hundred feet high and half a mile long, two days later there were forty in sight at day break of all sorts and conditions, some of a dirty green, others brown, if white ice had not been about they

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
38	Oct. 1, 1892	Roderick Dhu ...	49 S.	43 W.	might easily have been mistaken for land. No perceptible change of temperature of air and sea both 49°. At 5 p.m. the sea was 2° colder and shortly after a huge iceberg appeared on the weather bow. At midnight the ship seemed to have run into a bay so stood out again. The majority of the icebergs were black, those level with the water most dangerous. Having cleared this barrier, very soon another similar barrier was raised, looking like a solid wall of icebergs three hundred feet high. The ship got safely through a passage about five hundred feet wide; these icebergs seemed all in a state of speedy dissolution, one having a submerged promontory of about four hundred feet, another barrier came into view almost immediately, but its icebergs were smaller and more scattered.
			43 S.	33 W.	Passed last ice.
39	Oct. 17, 1892	Curzon	44 S.	31 W.	In sight of fifty icebergs, some of which were five hundred to one thousand feet high.
40	October, 1892	Urania	43 S.	35 W.	Sailed one hundred and fifty miles along a solid icy mass, stretching from east-south-east to west-north-west without any visible opening.
41	Oct. 14, 1892	Coptic	46 S.	180 – 174 W.	Met some enormous icebergs, two hundred and fifty feet high.
42	...	Aorangi	46 S.	178 E.	Within twenty-four hours of leaving Lyttleton, New Zealand sighted many icebergs.
		,, ...	50 S.	171 W.	
		,, ...	54 S.	135 W.	Several more seen and a quantity of small ice.
43	Oct. 19, 1892	Star of England ...	...	...	The morning after leaving Lyttleton, New Zealand, saw huge iceberg, a little later engines had to be stopped;

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
43	Oct. 19, 1892	Star of England ...	...	...	completely surrounded by icebergs, nothing but ice three hundred feet high could be seen from aloft. Cleared this during the afternoon and kept away to the north of the Chatham Islands.
	Oct. 20, 1892	„ ...	43 S.	170 W.	At 11 p.m. passed another large iceberg; passage said to have been lengthened at least two days.
44	Oct. 23, 1892	Liverpool	55 S.	94 W.	Sighted an iceberg eight hundred feet high and half a mile long.
45	Nov. 3, 1892	John Ena	46 S.	16 W.	Saw a large iceberg.
46	...	Superb	40 S.	28 W.	Passed ice on the fortieth parallel between the twenty-eighth and twenty-first degrees west longitude. In considerable danger on several occasions; icebergs much discoloured by brown layers and irregular patches. In daylight with no white ice in the vicinity, some of these would have been taken for rocks, and it is believed that some of the vigias in this part had their origin in ice of this description.
47	Dec. 28, 1892	Florence	48 S.	45 W.	Sighted eight to ten icebergs, eight to ten miles long, four miles broad and two hundred feet high.
48	Dec. 29, 1892	Drumcraig	...	...	In almost the same position as No. 47, observed a large ice island fully three hundred feet high and twenty to thirty miles long.
	Dec. 31, 1892	„	47 S.	46 W.	Other icebergs sighted up to this date.
49	Jan. 10, 1893	Arthurstone	49 S.	44 W.	Collided with iceberg, pieces of ice weighing several hundred tons fell from the summit into the sea.
50	Jan. 10, 1893	Candida	50 S.	40 W.	Sighted much ice, thirty-five immense icebergs above the horizon at one time.
	Jan. 12, 1893	„	48 S.	42 W.	

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
51	Jan. 13, 1893	John Cook	...	...	Surrounded by icebergs in the South Atlantic, many large ones seen, and next morning at least thirty all round, one being six hundred feet high and a mile long, at noon hemmed in on every side, fifty in sight ranging from one hundred to six hundred feet in height.
52	Jan. 15, 1893	Breidablik	49 S.	44 W.	Saw two tabletopped icebergs, two hundred feet high and two miles long, next day saw four more.
53	Jan. 17, 1893	Erroll	47 S.	51 W.	Passed fifty icebergs.
	Jan. 18, 1893	,, ...	48 S.	44 W.	Passed three more.
54	January 1893	Kenilworth	48 S.	77 W.	Two days in ice; in all about twenty-five icebergs sighted some five hundred feet high, and one three miles long.
55	Jan. 10, 1893	Wasdale	47 S.	42 W.	Passed small pieces of ice in early morning, afterwards completely surrounded by icebergs, one three hundred feet high and three miles long, on the 11th at sunrise, she was in a horse-shoe shaped bay twenty miles deep, ten miles across the middle, and four miles at the entrance; passing one iceberg a great quantity of sand was noticed running in seams and giving it the appearance of marble.
	Jan. 11, 1893	,, ...	47 S.	42 W.	Last ice seen.
56	..	Strathcathro .	...	...	In company with the Wasdale in the ice bound bay.
57	Jan. 17, 1893	Loch Torridon ...	53 S.	46 W.	Sighted two large icebergs.
	Jan. 19, 1893	,, ...	51 S.	46 W.	Threaded her way between numerous icebergs from a quarter to three miles in length and five hundred to a thousand feet in height. In the afternoon sailed fifty miles along one side of an immense ice island from south to north, its extent to westward could not be determined, nothing but ice visible in that direction

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
57	Jan. 20, 1893	Loch Torridon ...	...	...	from aloft. The bays and indentations along its coast were full of icebergs and detached ice; until 8 a.m. of the 20th innumerable icebergs were passed, at this time saw one to eastward probably exceeding all other previous measurements, it was at least three miles long and 1,500 feet high.
58	Jan. 28, 1893	Clan McLeod .	...	...	Passed icebergs fifteen to twenty miles long and a dozen others, several of which were two hundred feet high.
59	Feb., 1893 ..	Grandee	42 S.	43 W.	Sailed between icebergs for two hundred and fifty miles.
60	1893	Berean	51 - 46 S.	45 - 40 W.	Passed twelve huge icebergs between these positions.
61	Mar. 3, 1893	Anglesey	52 S.	46 W.	Sailed among icebergs for three hundred miles.
62	Mar. 4, 7,/93	Penrhyn Castle ...	51 - 47 S.	50 W.	Sighted many icebergs.
63	Feb. 16, 1893	Loch Rannoch ..	51 S.	49 E.	Just grazed large iceberg with yard arms, this iceberg was four to five hundred feet high and a mile long; sea temperature gave no warning. In the morning ice was all around and one iceberg had a large brown rock imbedded in it.
64	Jan. 21, 1893	Solingen	42·12 S.	53·51 E.	Saw an iceberg three hundred feet long and one hundred feet high.
65	Mar. 9, 1893	Turakina	51 S.	47 W.	Passed first iceberg.
	Mar. 10, 1893	,, ...	...	...	At 5·30 a.m. the whole horizon was thickly studded with icebergs, backed by an unbroken wall.
	Mar. 11, 1893	,, ...	...	...	At 4 a.m. the whole leeward horizon was thickly studded with icebergs and at 7 a.m., went through the last of them.
66	Feb. 25, 1893	Westbury	51·47 S.	48 W.	Sighted ice at 4·30 p.m., saw an immense ice island stretching to the S.S.E.
	Feb. 26, 1893	,, ...	...	...	At 6 a.m. no opening to the N., all solid ice four hundred

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
					feet high, steep too. At 10 a.m. sighted great number of icebergs to the S.E.; 11 a.m. small ice to the E., sighted opening to the N., steered through and found the sea in every direction full of immense icebergs and broken ice; hove to for night.
66	Feb. 27, 1893	Westbury	49·40 S.	44 W.	At 4 a.m. fourteen icebergs in sight, noon three icebergs to the east; 2 p.m. passed large iceberg, the last.
67	Mar. 14, 1893	Aldergrove	51·2 S.	50·10 W.	Sighted several icebergs.
	Mar. 15, 1893	,, ...	50·36 S.	48·8 W.	Passed ninety-nine icebergs from daylight till noon with a great amount of small ice.
	Mar. 16, 1893	,, ...	49·10 S.	46·36 W.	Small floe ice continually rubbing alongside; at 4·30 p.m. sailed into a clear space of about six miles by four but could see no safe passage to enter.
	Mar. 17, 1893	,, ...	...	...	At 3 a.m. large iceberg close on the beam; 4·30 a.m. just cleared another iceberg; at 11 a.m. passed the last iceberg. Some of the icebergs were like islands, at least three or four miles in length and two hundred feet high; some were huge square blocks, others all shapes and forms.
68	March. 1893	Stronsa	57 S.	50 W.	Saw large ship which had collided with icebergs, and in dangerous proximity to ice floes. A barque appeared from behind some icebergs and rendered assistance.
69	Jan. 7, 1888	Cutty Sark	62 S.	179 W.	Passed four icebergs.
	Jan. 8, 1888	,, ...	62·25 S.	172·47 W.	Passed six icebergs from one hundred and fifty to three hundred feet high.
	Jan. 9, 1888	,, ...	62.25 S.	164·15 W.	Passed five icebergs about the same size as yesterday.
	Jan. 10, 1888	,, ...	62·19 S.	155·2 W.	Passed nineteen icebergs ranging from a quarter to three miles long, and from two hundred and fifty to three hundred feet high.

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
69	Jan. 11, 1888	Cutty Sark	62·41 S.	148·5 W.	Passed over one hundred icebergs, counted eighty-seven large ones in sight at one time, same size as on 10th, besides innumerable small ones; as we passed close between two, the thermometer fell to 31°, breath frozen on moustache.
	Jan. 12, 1888	,, ...	62·38 S.	143·32 W.	Passed eighty icebergs ranging from two to three hundred and fifty feet high, and a quarter to one and a half miles long; 13th and 14th saw no ice.
	Jan. 15, 1888	,, ...	63·25 S.	120 W.	Passed one iceberg.
	Jan. 16, 1888	,, ...	63·30 S.	120 W.	Passed four icebergs.
70	Jan. 23, 1893	,, ...	59·7 S.	160·35 W.	Saw two icebergs about two hundred and fifty feet high, and a quarter of a mile long.
	Jan. 24, 1893	,, ...	60·39 S.	155·53 W.	Passed nine large icebergs.
	Jan. 25, 1893	,, ...	60·53 S.	150·23 W.	One continuous line of icebergs on both sides, thirty in sight at one time.
	Jan. 26, 1893	,, ...	60·53 S.	143·31 W.	Icebergs too numerous to count on both sides, two hundred and fifty to four hundred feet high.
	Jan. 27, 1893	,, ...	61·25 S.	131·55 W.	Not so much ice to day, only saw one more iceberg this side of Cape Horn.
	Feb. 8, 1893	,, ...	50·8 S.	46·41 W.	Ran in amongst a great number of icebergs of all sizes and shapes, one I estimated to be 1,000 feet high, sometimes reports like that of an eighty ton gun being fired would be heard. Sailed eight miles along side of one iceberg but did not see the end, another appeared ahead and I had to go between them. Saw an immense passage about 1,000 feet wide, with ice on either side four hundred feet high, from cross bearings and distance run, I found one side of this passage to be nineteen and a half

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks,
					miles long and quite flat. Looking back through the passage and seeing the number of icebergs and broken ice, one wondered how we got through in safety. Last voyage we saw no ice after rounding the Horn, though I passed the same place.
71	May 17-20/93	Duncraig	52·48 S.	45·20 W.	Passed a great number of small and large icebergs.
72	May 27-29/93	Highland Forest ...	N.Z. to	London ..	Passed over one hundred and fifty icebergs from a half to one mile long and from three hundred and fifty to five hundred feet high.
73	Mar. 10, 1893	Soukar	52·17 S.	45·56 W.	Sighted a small iceberg to windward and from that date to March 18, they were amongst the thickest drift ice ever known in these latitudes. Some of the icebergs were from ten to twelves miles long, quite flat with perpendicular sides from two to three hundred feet in height, others that had turned over displayed very ragged peaks.
74	August, 1893	Nora	...	...	On arrival at Sydney from New York in Oct. 1893, reported that a week before making the Cape of Good Hope she sighted a great number of icebergs of all shapes directly in the track of outward bound ships to the Colonies.
75	Oct. 29, 1892	...	Chatham Islands New Zealand		Mr. Gascoigne, Resident Magistrate of the Chatham Islands, reported that several icebergs were off the island and some stranded amongst the rocks at Pitt Island. One five hundred feet high, another nearly half a mile long; they remained in sight a few days and then broke up.
76	October, 1893	Fortuna	40·50 S.	1·21 W.	Began sighting ice in this position. On Oct. 22 passed several large icebergs one a mile and a half long and six hundred feet high.

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
76	October, 1893	Fortuna	45 S.	26·44 W.	Sighted a large iceberg about two miles long and six hundred feet high, after this fully one hundred smaller ones were seen, the ship being at times completely surrounded.
77	Nov. 4, 1893	Ossea...	43 S.	6 W.	On voyage from Rio sighted six enormous icebergs, five or six hundred feet high ; for the following nine days the vessel was sailing through a field of ice, as many as one hundred and twenty icebergs were seen in one day. Another day so many were in sight that count was lost; entirely surrounded for three days.
		,, ...	46 S.	30 E.	Last ice seen.
78	Nov.and Dec. 1893	Colonial bound ships	In the the Cape	vicinity of of Good Hope	*Sydney Morning Herald*, 3 1 94—Ice reported both east and west of Cape of Good Hope, floes of from one to two miles in extent, and icebergs from six to eight hundred feet in height. All the shipping reports point to a difference of from four to six degrees between the two Oceans, the ice in the Indian being that much farther south than in the Atlantic Ocean.
79	Dec., 1893 ...	Levernbank	...	...	On voyage from Rio de Janeiro to Newcastle N. S. Wales, during three days upwards of seventy large icebergs and miles of floating ice were met with.
80	Dec. 8, 1893	Persian Empire ...	45 S.	13 E.	In the vicinity of several icebergs. From 8th to 14th more or less surrounded by ice, the icebergs extended for 1,300 miles, and an unbroken field of ice thirty-five miles in length, and forty to fifty feet high was sighted, other icebergs estimated from one to two miles in length and one to five hundred feet high.
	Dec. 14, 1893	,, ...	46 S.	44 E.	
81	January 1894	Lodore	45 S.	20 E.	Ice fallen in with, numerous icebergs seen thence to 45° S.
			45 S.	40 E.	40° E., some of the icebergs were five to eight hundred

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
					feet high, and one fully a mile in length; water between the ice islands covered with broken ice. Ship covered about 1,500 miles before she got clear.
82	Feb. 11, 1894	Bungaree	44·53 S.	35·17 E.	Passed three icebergs two hundred feet high, one 1,000 feet long.
	Feb. 12, 1894	„	Near Prince Edward's Island		Passed fifteen icebergs up to one hundred sixty-five feet high and eight hundred feet long, also passed several others.
	Feb. 13, 1894	„	46·30 S.	45·3 E.	Passed iceberg one hundred and sixty feet high and six hundred and eighty feet long, and at 3·30 p.m. passed a small one in 46·34 S. and 46·50 E.
			46·34 S.	47 E.	Passed two icebergs. All of these dimensions were measured carefully with a sextant.
83	Feb. ..., 1894	Blairhoyle	41 S.	...	A few days before reaching the meridian of the Cape of Good Hope a number of icebergs were fallen in with.
			51 S.	78 E.	From 41° S. to this position an average of from fifty to sixty icebergs were passed each day, some of them over eight miles long; for ten days the vessel was sailing through icebergs. About the meridian of Desolation Island two icebergs were passed, the last seen.
84	May .., 1894	Normandy	42·46 S.	9 E.	Passed a lot of floe ice about six feet above the water.
85	June ..., 1894	H.M.S. Garnet ...	45·45 S.	60·45 W.	Ice island about ten miles in length apparently, position approximate; this one is farther west than any yet seen.
86	Nov. 5, 1894	Antarctic	56·57 S.	...	Sailing from the Campbell Islands met the first iceberg of considerable size.
	Nov. 6, 1894	„	58 S.	...	Sighted an immense body of ice stretching away from the south-east in a north-westerly direction for a distance of not less than from sixty to eighty miles, and

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
					about sixty feet in height at least. This huge barrier was apparently quite flat and level on the top, and on account of its greyish colour all over, for a time was taken for an island, could only account for its dark colour by supposing it to have been detached from the vicinity of some volcanic islands towards the south, for instance, the Bellamys, the dark grey colour might thus possibly be a layer of lava, we gave this monster of floating or aground ice a wide berth, and the following day saw only a few ordinary sized icebergs.
87	Jan. 24, 1895	Morayshire	45·30 S.	51 E.	Saw a very large iceberg.
88	Feb. ..., 1895	Maccallum More ..	44·20 S.	21·33 E.	Passed nine icebergs to 33·50 E., one half to two miles in length and two to three hundred feet high.
	Mar. 2, 1895	,, ..	45·36 S.	111 E.	Sighted a very large iceberg about three miles long and three or four hundred feet high.
89	Oct. 29, 1894	Ladas	50·3 S.	60·10 W.	Saw a very large iceberg.
	Mar. 1, 1895	,, ...	52.52 S.	29·22 W.	At 8 a.m. continuous field of ice for six or seven miles; 7 p.m. ice right ahead and round to four points on the lee bow without a break, sailed six hundred miles at least round it, highest peak about three hundred feet.
	Mar. 4, 1895	,, ...	51·15 S.	19·6 W.	Numerous icebergs in the morning, passed several during the day, all small pieces.
	Mar. 5, 1895	,, ...	50·50 S.	14·47 W.	Passed about twenty-five or thirty icebergs to-day, mostly small one or two about three hundred feet high.
	Mar. 6, 1895	,, ...	50·56 S.	9 12 W.	Passed numerous icebergs.
	Mar. 7, 1895	,, ...	50·52 S.	3·18 W.	Icebergs seemingly as thick as ever, at 8 a.m. counted seventeen ahead from beam to beam; ice still about in evening, many icebergs passed.

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
89	Mar. 8, 1895	Ladas	50·14 S.	1·45 E.	Numbers of icebergs around from two hundred feet in height to pieces awash.
	Mar. 9, 1895	,, ...	48·19 S.	3·43 E.	Only an occasional piece seen.
	Mar. 11, 1895	,, ...	46·56 S.	6·56 E.	Passed two large pieces of ice.
	Mar. 12, 1895	,, ...	47·15 S.	10·41 E.	At 11 p.m. a number of icebergs sighted from ahead to starboard beam, changed course, ice still ahead after awhile, then stood out back as we had come in.
	Mar. 13, 1895	,, ...	46·47 S.	13·50 E.	At daybreak saw seventeen large icebergs from ahead to each beam but well apart; ice seemed in a line north and south, extending some twenty miles east and west, but how far the other way could not tell.
	Mar. 14, 1895	,, ...	47·42 S.	16·30 E.	Passed several icebergs, two of good size.
	Mar. 16, 1895	,, ...	49·5 S.	23·53 E.	Saw a few pieces of ice at 8 p.m., passed several small pieces and one very large iceberg.
	Mar. 17, 1895	,, ...	48·53 S.	28·25 E.	Icebergs sighted, seven in a line.
	Mar. 18, 1895	,, ...	48·53 S.	31·25 E.	At daybreak ice around in all directions, passing icebergs at intervals all day.
	Mar. 19, 1895	,, ...	48·2 S.	36·33 E.	Passing icebergs all the time.
	Mar. 20, 1895	,, ...	47·50 S.	42·33 E.	Occasional icebergs passed; the barometer frequently rose rapidly when nearing any vast quantity of ice, the thermometer remaining steady.
90	Mar. 16, 1895	Largiemore	47 S.	11·33 E.	Met with ice.
	Mar. 21, 1895	,, ...	44 S.	28 E.	From the 16th to the 21st the ship was in danger, at one time completely surrounded by icebergs; from the topsail yard nothing but a magnificent series of ice islands could be seen on the fifth day from the time the ice was fallen in with, the vessel succeeded in getting clear, and the captain states that he must have

Ref No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
					sailed through about eight hundred miles of ice.
91	March, 1895	Germanic	42·50 S.	43·30 E.	Passed two icebergs and a lot of pieces.
92	Mar. 15, 1895	Shenir	44·58 S.	30·46 E.	Passed five large and numerous small bergs.
	Mar. 17, 1895	,, ...	...	..	Passed two icebergs and a lot of field ice.
93	Mar. 28, 1895	Tweedsdale	44·50 S.	21·6 E.	Six icebergs seen; vessel was three days in sight of ice, the icebergs ranged to seventy feet high and half mile long.
94	April 4, 1895	Zuleika	44 S.	22·30 E.	Four icebergs and several small pieces passed.
	April 5, 1895	,, ...	44 S.	26 E.	Passed several large icebergs on each side.
	April 6, 1895	,, ...	44 S.	30·30 E.	Had to alter ship's course to pass icebergs, nine large ones being in sight at one time.
	April 8, 1895	,, ...	44·19 S.	36·20 E.	Passed one iceberg and several small pieces, no more seen afterwards.
95	April..., 1895	Firth of Solway ...	43 S.	32 E.	Sighted three icebergs each about fifty feet high and one hundred feet wide.
96	April 4, 1895	Lowther Castle ...	46·15 S.	16·30 E.	Met large iceberg 1,000 yards long, four hundred feet high, apparently extending some distance under the water.
	April 5, 1895	,, ...	...	...	Passed over fifty large icebergs.
	April 6, 1895	,, ...	44·40 S.	25 E.	Ship completely surrounded, over one hundred being in sight, one measured by sextant being six hundred and thirty-five feet high. The southern horizon was a solid wall of icebergs and ice islands two or three miles in length, we also passed a great many next day.
	April 10, 1895	,, ...	47 S.	37·20 E.	Several marvellous escapes, passing within two hundred feet of large icebergs.
	April 14, 1895	,, ...	46 S.	49 E.	Saw last iceberg, having been amongst ice for ten days.
97	April .., 1895	Earnoch	...	...	On arrival at Wellington, N.Z., from Liverpool, reported that for six days she was almost entirely surrounded by icebergs. She passed between eight and nine hundred,

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. '	Remarks.
					some being three miles long and six hundred feet high.
98	April..., 1895	Lady Lawrence ...	45 S.	...	On arrival at Sydney from Liverpool, reported that icebergs were met in 45° S. The ship sailed through an immense pack for five days, icebergs large and beautifully shaped a quantity of loose ice floating about.
99	April..., 1895	Imberhorne	...	19, 31 E.	Ship five days amongst ice after crossing the meridian of the Cape of Good Hope.
100	April 27,1895	Craiglands	42·25 S.	26 E.	Passed a very large iceberg.
	April 28,1895	,, ...	42·22 S.	30 E.	Passed two more icebergs.
101	April 30,1895	Crocodile	40·20 S.	20 E.	At 2 a.m. ran between two enormous icebergs and for six hours the vessel passed numerous others.
102	April 24,1895	Oronsay	44·43 S.	24·48 E.	Met first ice.
	April 25,1895	,, ...	43·52 S.	26·23 E.	Numerous icebergs, thirty-four in sight at one time, some very large.
	April 27,1895	,, ...	43·6 S.	32·55 E.	Five icebergs seen.
	April 27,1895	,, ...	42·48 S.	35·50 E.	Last ice seen in afternoon.
103	April 21,1895	Erin's Isle	47·8 S.	18·30 E.	Sighted first ice none exceeding one hundred and twenty feet in height and two or three hundred feet in length, none seen in night.
	April 22,1895	,, ...	47 36 S.	21·46 E.	Saw two icebergs about two hundred feet high, one half a mile square, the other three quarters of a mile long and one-third of a mile wide.
	April 23,1895	,, ...	47·10 S.	22·50 E.	Saw three large icebergs and five small pieces, largest two hundred and twenty feet in height.
	April 24,1895	,, ...	46·44 S.	27·46 E.	Passed about thirty icebergs and some smaller ice.
	April 25,1895	,, ...	44·55 S.	30·1 E.	Passed a great number of icebergs, at times had to alter our course to clear them, the largest was one hundred and sixty feet high, four miles long and two broad.
	April 26,1895	,, ...	44·17 S.	31·20 E.	Passed three large icebergs; temperature of sea the last three days from 42° to 40° Fah.

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
	April 27,1895	Erin's Isle	43·38 S.	33·9 E.	Passed the largest iceberg we saw, probably five and a half to five and three-quarter miles long.
		,, ...			Saw no more ice after this one.
104	June..., 1895	Greta...	42·25 S.	47·5 E.	Passed between two large icebergs and sighted many others
105	June..., 1895	Bardowie	...	49 – 77½ E.	Sailed for over nine hundred miles between the longitudes of Madagascar and St. Paul without losing sight of huge masses of ice. Icebergs drifting to eastward and thawing rapidly. The masses of ice sighted last were less lofty than those first seen. Latitude not given.
106	June 16, 1895	Elstree Grange ...	42 S.	36 E.	Sighted an immense iceberg, two hundred feet high and fully a mile long.
107	June..., 1895	Star of Victoria ...	42·30 S.	30·40 E.	Sighted several large icebergs.
108	June..., 1895	Pass of Balmaha ...	43·10 S.	33·27 E.	Scores of icebergs in sight for two hundred miles, some as high as two hundred feet.
109	July 5, 1895	Gulf of Lyons ...	43 S.	43·29 E.	Fell in with icebergs and floe pieces, in sight for three days.
110	July 27, 1895	Port Chalmers ...	...	...	After rounding the Cape of Good Hope collided with an immense iceberg, 1,500 miles from Mauritius and 4,700 from Adelaide. Arrived safely in Sydney.
111	Feb. 11, 1895	Hawkes Bay... ...	45·30 S.	...	Voyage from London to Australia, met first ice, two icebergs about four hundred feet high; at one time fairly surrounded by ice, and on 16th counted eighteen icebergs, ranging from two to five hundred feet in height.
	Feb. 16, 1895	,, ...	...	...	
	Feb. 25, 1895	,, ...	47 S.	107 E.	Saw several icebergs, the last on voyage.
112	Feb. 14, 1895	East Lothian ...	...	...	Sighted a large iceberg in the vicinity of the Crozets.
113	July 23, 1895	Bungaree	43·13 S.	51·19 E.	Passed an iceberg fifty feet high, three hundred feet long one mile distant. Temperature of air 39°, water 40°.
	July 24, 1895	,, ...	43·15 S.	56·29 E.	Passed an iceberg about one hundred and fifty feet high

Ref. No.	Date.	Ship's Name.	Latitude. °	Longitude. °	Remarks.
					fifteen miles distant at 5·10 p.m. Temperature of sea water at noon 40°, at 4 p.m. 46°, at 5 p.m. 46° ; Temperature of air at 5 p.m, 43°.
114	Aug. 10, 1895	Gulf of Venice ..	45 S.	54 E.	Icy region fallen in with three icebergs sighted.
115	July 12, 1892	Nairnshire	...	...	On voyage, New Zealand to London, 1,750 miles from Otago passed one very large and six small icebergs.
116	July ..., 1895	Avoca...	42 S.	40 E.	Passed an enormous iceberg many miles long and several hundred feet high.
117	June 28, 1895	Nairnshire	43 S.	...	After crossing the meridian of the Cape of Good Hope sighted icebergs, two estimated to be two hundred feet in height.
	June 30, 1895	,, ...	44 S.	53 E.	Several smaller icebergs fallen in with.
118	May..., 1895	Derwent	43 S.	38 E.	Met several large icebergs, ship not clear till she had sailed two hundred miles east.
119	July 9, 1895	Armida	42·26 S.	42·55 E.	Sighted several large icebergs, one estimated at four hundred feet and three quarters of a mile in length.
120	July ..., 1895	Karoo...	43·30 S.	40·52 E.	Passed numerous icebergs and large quantities of broken ice, one iceberg about eighty feet in height and a quarter of a mile in length.
121	July 25, 26, 95	Aberdeen	45·35 S.	59 E.	Large ice island passed ; several large icebergs seen.
122	July ..., 1895	Wray Castle ...	42 S.	43·30 E.	Voyage Liverpool to Sydney, three icebergs sighted 1,500 miles this side of Cape of Good Hope ; one of enormous size, half a mile long and three hundred feet high, smaller ice also seen.
			47 & 48 S.	...	Ship driven down to 47 and 48° S., met with clear seas, not a vestige of ice being seen.
123	July 14, 1895 July 15, 1895	Algoa Bay	43 S.	49 E.	Passed a large quantity of ice, most of the icebergs were fallen in with on July 14 and 15.

On reference to the chart of icebergs given with this paper and the tabular statement, it will be seen that between January and July 1895, a vast number of icebergs were reported between the Cape of Good Hope and Australia, and it is remarkable that from the end of July to the present time, (November 28th) no ice has been reported in this region, except three icebergs sighted on August 10, by the Gulf of Venice (No. 114), Lat. 45° S., Long. 54° E. The only reason for the sudden disappearance of these vast fields of ice that I can suggest, is the prevalence of strong North-west winds over the Southern Indian Ocean, this is shown by the logs of ships traversing these waters.

It is noteworthy that the ice which came with the great outburst in 1854-5 also disappeared quite suddenly, as we are told by Towson, writing in 1858, who says, "Since April, 1855 however, the only reports of icebergs are much farther south."

In the reports of various ships in the foregoing list, the question of change of temperature in air and water in the neighbourhood of ice is left in a very undecided state, the reports being very contradictory, (Nos. 29, 32, 34, 36, 38, 63, 69, 89, 103, and 113).

Icebergs more or less discoloured are reported in Nos. 14, 15, 19, 26, 27, 38, 46, 55, 63, and 86, and in No. 46 it is suggested that "Vigias" may originate by the grounding of one of these coloured icebergs, thus giving rise to the report of an uncharted island.

Very large icebergs are reported in Nos. 10, 13, 17, 24, 26, 27, 29, 33, 34, 39, 47, 48, 55, 56, 57, 58, 69, 70, 73, 80, 81, 83, 84, 86, and 103.

In the foregoing list of icebergs the one farthest north (No. 31) was in 37° S. We learn from "Towson," page 6, that in January 1850, an iceberg was in sight from the Cape of Good Hope in latitude 34° S.

On some NEW SOUTH WALES and other MINERALS.

(Note No. 7.)

By A. Liversidge, M.A., F.R.S.,
Professor of Chemistry in the University of Sydney.

[*Read before the Royal Society of N. S. Wales, November 6, 1895.*]

Antimonite—Queensland.

A hard splintery variety, breaking with a conchoidal fracture with somewhat hackly surfaces; noticeable as containing silica and barytes in thin veins or joints.

Analysis.

Antimony	64·47
Sulphur	26·59
Iron	1·00
Silica	3·41
Barium sulphate	2·63
Undetermined and loss	1·90
	100·00

The above is the mean of two analyses. Sp. gr. 4·43.

Apatite, Plumbiferous—Calcium fluo-phosphate. Broken Hill.

Some specimens of apatite containing lead were forwarded to me by Mr. S. Harris, from Block 14 Mine for examination.

The apatite is in the form of small grey imperfect crystals, (some however are symmetrical hexagonal prisms closed by the pyramid and terminal pinacoids) about $\frac{1}{16}''$ long, in cavities in a matrix of dark blue-black honey-combed crystalline zinciferous galena; the freshly fractured apatite has somewhat the lustre and appearance of pyromorphite. It is probable that part of the calcium phosphate of the apatite is replaced by the isomorphous lead phosphate.

The crystals of apatite were separated as carefully as possible from the galena, but this could not be done completely, as small crystals of galena are seen within the apatite crystals, *i.e.*, when sliced and examined under the microscope.

Mr. Harris states that pyromorphite was met with in the shallower parts of the same portion of the mine in considerable quantities. He found 3·9% of fluorine, ·5% manganese monoxide, and 36·25% of phosphoric pentoxide, but as all the specimens I examined showed enclosed lead sulphide, I do not quote his amounts of lead and lime; the proportions of phosphoric oxide and fluorine indicate that the mineral answers to the general formula of $3\,Ca_3P_2O_8, CaF_2$, in which part of the Ca is probably replaced by Pb.

Barklyite—Two Mile Flat, Mudgee, N.S.W.

Collected by the late Prof. A. M. Thomson, Sydney University.

The specimens were in small well rolled pebbles, not more than $\frac{1}{4}$" long. Most are of a kind of dull magenta colour and usually show one or two light streaks or veins, in others, the colour might be referred to that of lean beef. Hardness about 8·5, *i.e.*, less than 9. Sp. gr. 3·738 at 18·5° C.

The mineral is tough, and the fracture granular and of a pink tint, the powder is also of a pale pink tint. Before the blowpipe it darkens a little and returns to its former colour on cooling. After ignition it is a little more opaque, probably due to slight disintegration. When strongly heated, it becomes brilliantly luminous and gives a blue colour with cobalt nitrate. Large quantities gave the chromium reaction with micro-cosmic salt and borax beads. The precipitate of $Al_2O_3 3H_2O$, fused with $NaKCO_3$ gave the manganese reaction in one case but not in others.

No full description of this mineral appears to have been published; the name Barklyite was given to it by Mr. Geo. Milner Stephen, F.G.S., after the then Governor of Victoria. In a catalogue of his collection, and in a lecture, he refers to

them as violet rubies, or barklyite, from the Ovens district in Victoria.[2] Apparently, too, it has never been met with in any quantity, and the variety does not appear to be sufficiently distinct to warrant a special name.

It consists principally of alumina, (Al_2O_3) but the analysis in hand is not yet completed.

Chrysocolla—Hydrous copper silicate. Broken Hill, N.S.W.

As incrustations and stalactitic forms, with mammillated surfaces, of a sky blue and green colour. Vitreous lustre in parts. Conchoidal fracture. Hardness 4. Streak, pale blue. Effervesces slightly on warming with HCl, from the presence of a little copper carbonate. Before the blowpipe, it darkens and breaks up slowly with decrepitation. In tube it gives off much water and a nitrogenous odour. Soluble in HCl and HNO_3 with a residue of silica.

Beryl—Vegetable Creek, New England, N.S.W.

Described in a paper read before this Society, December 2, 1891. Sp. gr. 2·80. Hardness, 7·5.

Analysis.

Silica	67·4
Alumina	18·5
Beryllia	12·9
Iron sesquioxide	·6
Lime	...traces.
	99·4

Crocoisite—Dundas, Tasmania.

In brilliant crystals of a deep orange-red colour, about $\frac{1}{2}$" long, seated on a mangano-ferruginous matrix. The Dundas mines have yielded some fine groups of crocoisite crystals, with the prisms several inches long; associated with cerussite, galena and occasionally anglesite and other lead minerals. Hardness, 2·5. Sp. gr. 5·92.

[1] Trans. Roy. Soc., Vict., 1865, p. 70.

Analysis.

Lead monoxide ...	...	...	...	66·86
Chromium tri-oxide	...	...	...	30·99
Iron sesquioxide ...	...	...	...	1·02
				98·87

Which corresponds with the formula $PbCrO_4$.

FAHLERZ—Wiseman's Creek, *via* Brewongle, N.S.W.

Occurs in quartz veins. Collected in September, 1888. No crystals were obtained.

Analysis.

Copper	...	...	...	...	33·004
Lead	...	...	...	...	·630
Iron	...	...	...	...	2·844
Zinc	...	...	...	..	3·693
Antimony	...	...	...	...	34·620
Sulphur	...	...	...	...	25·207
Nickel	...	...	...	...	trace.
Cobalt	...	...	...	...	trace.
					99·998

The above corresponds approximately to $\frac{4}{5}$ CuS, $\frac{1}{5}$ (FeZn) S, Sb_2S_3.

Some silica was obtained in the analysis, but this was deducted and an allowance made for it in the calculation, as it obviously belonged to the matrix.

A special examination was made for gold and silver on a larger quantity, when 31 ozs., 17 dwts., 0 grs. of silver, and 2 ozs., 13 dwts., 8 grs. of gold per ton were found.

ILMENITE—Cloncurry River, Queensland.

Black, with traces of crystal planes, breaks with well-marked metallic lustre.

Analysis.

Titanium dioxide, TiO_2	...	...	...	49·85
Silicon „ SiO_2	...	...	...	1·01
Iron monoxide, FeO	...	...	...	35·70
Iron sesquioxide Fe_2O_3	...	...	...	13·22
				99·78

Manganese and magnesium are usually met with, but they and other metals, although specially sought for, were not found in this specimen. Dana gives the following extremes:—

TiO_2 = 59·20 to 3·55 %

FeO = 46·53 to 3·26 %

Fe_2O_3 = 93·63 to 1·20 %

Zinciferous Galena.

This mineral was sent to me from Broken Hill as clausthalite, the selenide of lead. Before the blowpipe it yielded the reactions lead, zinc, and sulphur, with a little arsenic, but I could not get any reaction for selenium. Decrepitates strongly. It appears to occur in nodular masses.

The mineral, in certain lights has a dull grey colour and scoriaceous appearance, but in other positions the light is reflected from it brilliantly with a bluish-grey metallic lustre; this is due to the fact that the surface is covered with minute cubical crystals, which have their planes more or less parallel, although at different levels; my specimens only exposed about two square inches, but I think it would be found to extend over larger surfaces. The effect is something like that of "shot" silk.

Under a 1" objective, the cubical character of the crystals are clearly recognisable, so also are the well marked cubical cleavage planes, which have a strong metallic lustre. The mineral appears to be homogeneous, and no separate portions of blende were detected in it, so that the two sulphides seem to have been deposited together; thin films of arborescent copper pyrites occur on some of the surfaces, and within crevices. Sp. gr. at 18° 6·72. It is slightly harder than galena.

The nodules only contain a little zinc; but they have not yet been analysed; on assay they proved to be very rich in gold, and gave me 5 ozs. 17 dwts. 4 grs. per ton, and 0 oz. 19 dwts. 4 grs. of silver per ton: lead minerals are usually richer in silver than in gold.

The vein stuff gave—

Analysis.

	I.	II.	III.
Insoluble	3·16	3·47	
Lead...	60·20		61·014
Zinc	15·50	14·85	
Sulphur	18·94		
Iron	2·62		
Copper	·205		
Arsenic	traces.		
Antimony	traces.		
	100·625		

The proportion is about 3 PbS, $2\frac{1}{2}$ ZnS.

It seems to be related to the minerals huascolite and kilmacooite[1] but with fairly well marked differences. I do not, however, think it need be named; the term zinciferous galena describes it accurately without adding to the already excessive list of so-called new species of minerals.

LIMESTONE WITH CONE-IN-CONE STRUCTURE—Picton, N.S.W.

Evidently very impure, of a brown colour, and argillaceous appearance. An analysis of this was made in 1876, and forwarded to the Mineralogical Society, but lost in transit.

Composition.

Portion soluble in HCl :—

Water	2·10
Carbon dioxide, CO_2	30·01
Silica, SiO_2	1·63
Iron sesquioxide, Fe_2O_3	4·35
Manganese oxide, MnO	·52
Lime, CaO	38·19
Soda, Na_2O...	1·70
Portion insoluble in HCl	22·21
	100·71

The amount of calcium carbonate being 68·20. The portion insoluble in hydrochloric acid was not further examined.

[1] Dana's System of Mineralogy, 1892, p. 51.

The specimen was from a layer about three inches thick; the cones are fairly regular in size and shape, and run right through the deposit in vertical columns, like piles of small closely packed conical paper sugar bags; the average diameter being about half-an inch, and the length perhaps a little more, the angle of the cone being between fifty and sixty degrees, and incipient crystallisation is visible in parts. The upper surface of the deposit presents pits with thickened edges over some of the columns of cones.

Mr. A. J. Sach, F.C.S., published an account of this deposit (with an analysis) in the Report of the Australasian Association for the Advancement of Science, Hobart Session, 1892, p. 328.

Molybdenite.

This was described in Note No. 6, read before this Society, December 2, 1891, as occurring in large crystals $3 \times 3\frac{1}{2} \times 5\frac{1}{2}$" long from the Eleanora Mine, Kingsgate, near Glen Innes, N.S.W.

Composition.

	I.	II.
Molybdenum	57·31	58·66
Sulphur	42·00	41·23
Iron	1·50	·39
	100·81	100·28

Another specimen yielded about 6% of manganese oxide; but this was probably mechanically enclosed between the plates of molybdenite. **Sp. gr. 4·6.**

Proustite—Silver Sulpharsenide.

Mr. Edgar Hall, F.C.S., sent me, in August last, some specimens from his United Mine at Rivertree, in which he had found some minute red crystals. I have examined the crystals, and agree with him in regarding them as proustite. They are quite microscopic, and it is difficult to examine them and still more to separate them from the matrix.

Mr. Hall states that they occur in a narrow vein, about half-an-inch thick on the hanging wall, and that they have been

met with at seventy feet, one hundred and twenty feet, and one hundred and eighty feet levels, in fact all the way down so far. The lode is a contact one, between a dyke of quartz diorite and the massive granite of the country. The fissure is about eight feet wide at the one hundred and twenty feet level, of which about four feet is quartz carrying argentiferous minerals; the yield of silver is found to be much greater where the proustite crystals are present.

The crystals are on a bluish quartz, containing mispickel; they are of a full red colour, translucent, with vitreous lustre, and about $\frac{1}{16}$ to $\frac{1}{3}$ millimetre in length. I was able to obtain the reactions for arsenic, sulphur, and silver, but no attempt was made to make a quantitative analysis as it was only with difficulty that a few hundredths of a grain were obtainable.

Proustite is reported by Mr. C. Marsh[1] to occur also at Broken Hill.

Scheelite—Calcium tungstate, $CaWO_4$.

Lady Hopetoun Mine, Glen Innes, N.S.W.

Massive, coarsely crystalline, of a pale brownish stone colour. Hardness, 5. Sp. gr. 5·93, another portion 5·3 only.

A fairly pure calcium tungstate, containing a little water, 2·23% of silica, 1·52% of iron sesquioxide, and a trace of manganese.

Tinstone Crystals—Elsmore Mine, Inverell, N.S.W.

In stout pyramids, usually about half-an-inch through, but some of them are much larger. Very slightly water-worn at the edge, otherwise the crystals have the faces of the pyramid well developed and of a high metallic lustre. Yielded a white powder. Sp. gr. 6·68. Hardness. 6·5.

Analysis.

Tin oxide, SnO_2	94·60
Silica, SiO_2	2·00

[1] Geology of the Broken Hill Lode, &c., by J. B. Jaquet, p. 90. Sydney, 1894.

Iron sesquioxide, Fe_2O_3	1·67
Manganese oxide, MnO	·25
Tungstic acid, WO_3	·06
	98·58

Another specimen from the same locality, but water worn, was found to be harder = 7, with a sp. gr. of 6·54. The powder of this was brown.

Analysis.

Tin oxide, SnO_2	92·52
Silica, SiO_2	1·68
Oxide of manganese, MnO...	·98
Iron sesquioxide, Fe_2O_3	3·21
Tungstic acid, WO_3.	·36
	98·75

The loss of 1·25 on this, and 1·42 on the previous specimen, may indicate the presence of some of the rarer elements not specially sought for, and that the specimens are worthy of further examination.

Topaz—Shoalhaven District.

In the form of short columnar prisms, the terminal pyramidal planes not well developed, seated on granite. Of a greyish tint, more or less opaque, but translucent in parts.

Most of the crystals were about $\frac{1}{8}$″ to $\frac{1}{4}$″ in diameter, and about $\frac{1}{2}$″ long, closely packed together so as to form a solid layer of topaz next to the supporting rock. The crystals are brittle, some of the faces are slightly rough, as if etched. Hardness, 7·5 only. Sp. gr. 3·56.

Before the blowpipe it decrepitates, darkens, but becomes nearly colourless again on cooling. Gives off a little water when heated in tube.

Analysis.

Silica	28·19
Alumina	62·66
Fluorine	14·01
Water at 100°	1·21
	106·07

The above are the mean of the results of two closely agreeing analyses. The oxygen equivalent to the fluorine must be allowed for in the above analysis.

In the foregoing paper I was assisted by Mr. A. O. Black, a student in the Chemical Laboratory, who, under my direction, made several of the analyses; Mr. C. Walker, another student, analysed the ilmenite; Mr. J. A. Schofield, A.R.S.M., F.C.S., Demonstrator, the zinciferous galena; and Mr. J. M. Petrie, Junior Demonstrator, the fahlerz.

On a NATURAL DEPOSIT of ALUMINIUM SUCCINATE in the TIMBER of *GREVILLEA ROBUSTA*, R. Br.

By J. H. Maiden, F.L.S., and Henry G. Smith.

[*Read before the Royal Society of N. S. Wales, November 6, 1895.*]

The material upon which this investigation has been made was obtained from a Sydney timber merchant who was engaged in cutting up the well-known Silky Oak (*Grevillea robusta*, R. Br.) into planks. Finding a deposit in the middle of a log which "looked like whiting," as he expressed it, and thinking it curious, he sent it to the Museum, but before the log could be examined or the whole of the deposit collected, the planks had been sent away from the mill, and further examination of them could not be made. Nevertheless, about six ounces of the deposit had been secured, the examination of which forms the subject of this paper.

A large proportion of the substance must have been lost; what the amount was that the cavity originally contained we have no means of knowing. The investigation of this deposit has proved so interesting, that we would like to take this opportunity of directing the attention of those who are likely to become possessed

of like material, to the importance, from a scientific point of view, of submitting for investigation earthy-looking deposits which may be found in timber.

Physical Description.

The material is quite soft and almost white in colour, except on the exterior of the lumps, where they are slightly stained brown in places, by some organic substance. It has a sourish, rather unpleasant odour, arising most probably from the presence of acetic acid. The whole of the cavity appears to have been filled with the material; the largest lump measures in the thickest part 2 cm. or about three quarters of an inch, and impressions of the tissue of the wood can be easily seen.

The original material is crystalline in part, minute acicular crystals being seen between crossed nicols with a quarter inch objective. The harder and more solid portion appears to contain the crystals in very small quantity. The very soft portion contains them in abundance. The best method to observe them, is to mount a portion on a slide under a cover glass with water, no other material answering so well for this purpose. These acicular crystals were found to polarize when revolved between crossed nicols, but were altogether too minute to determine their mode of crystallization. The material is thus not quite amorphous.

Determination of the Base.

The organic matter is with difficulty entirely removed from the original substance by burning, the last traces of carbon requiring the heat of the blowpipe before being entirely removed. The residue is perfectly white in appearance, and shows no signs of fusion with the greatest heat obtainable with the gas-blowpipe. The residue is, when thus ignited, insoluble in acids, and requires fusion with bisulphate of potassium or other suitable substance before solution can be obtained. This residue contains no other base than alumina; absolutely no trace of lime could be detected in several determinations, and only the slightest trace was obtained when testing for magnesia. Quantitative determination gave

almost exactly one hundred per cent. of alumina in the ignited residue, as the result of two determinations. The method adopted was to fuse the ignited residue with bisulphate of potassium until solution was effected, and to dissolve in water when cold; the solution was then acidified, the alumina precipitated in the usual manner, and ignited before the blowpipe until of constant weight. The base therefore consists of alumina. Iron is absent.

Determination of the Acid.

In the systematic search for the acid, experiment showed the absence of oxalic, tartaric, citric, malic and benzoic acids in the solution obtained by boiling the acid solution of the original material with carbonate of soda, filtering, and proceeding in the usual manner; succinic acid alone being indicated, exclusive of a trace of acetic acid. The crystals obtained, as described below, answered all the tests for succinic acid. When the original substance is treated with a small quantity of nitric acid, it wholly dissolves, (the trace of organic matter other than the acid being destroyed): the solution is of a pale amber colour. On cooling, a mass of crystals separates out. These were filtered off, drained on a porous slab, and when dry, again heated with a small quantity of nitric acid, the crystals obtained by cooling, filtering, and drying on a porous slab as before. These operations were repeated three times, and at the conclusion the crystals were dissolved in water, a small quantity of animal charcoal added and filtered. The solution thus obtained was colourless; this was evaporated in the air after concentration on the water bath, white crystals being thus obtained. Although apparently pure, yet, on ignition, a small residue was left, for it appears to be exceedingly difficult to remove the whole of the alumina by solution and recrystallization of the acid. The crystals thus obtained were used to identify the acid, and for the qualitative tests generally, but for material for combustion sublimation between watch glasses was resorted to, the sublimate boiled with water for some time, concentrated, and allowed to crystallize at the ordinary temperature. (Of course this treat-

ment was not resorted to until qualitative tests had satisfactorily indicated that the acid was succinic acid only.) By boiling the sublimate with water, the succinic anhydride formed at the temperature needed for sublimation is converted into the ordinary acid, as is proved by the melting point, the sublimate before boiling with water melting at irregular temperatures between 125° C. to 150° C., while the normal acid, as obtained in crystals, melts at 177° C. to 178° C. uncorrected. As the melting point was determined in an open beaker in glycerol, the actual temperature for the column of mercury could hardly be accurately taken for correction of melting point, so the figures are given as obtained, but the melting point may be considered as closely approximating 180° C. The crystals are acid to the taste. The adherent moisture was removed from the crystallized acid by heating on the water bath before taking samples for combustion. The combustions were made of the acid obtained as pure as possible, absolutely free from residue on ignition, and melting at 178° C. uncorrected.

·2090 gram. gave ·3097 gram. CO_2
and ·1000 gram. H_2O
equal to 40·413 per cent. carbon
5·316 „ hydrogen
54·271 „ oxygen

100·000

equal to 3·368 C.
5·316 H.
3·392 O.

from which we may deduce the formula $C_4H_6O_4$, which is that of succinic acid.

Another combustion gave almost identical results.

Theory gives for $C_4H_6O_4$

40·678 C.
5·084 H.
54·238 O.

100·000

Besides these results of melting point and combustion, the acid gave perfectly all the qualitative reactions necessary for succinic acid. When the succinic acid was crystallized in the most successful manner, good monoclinic crystals were obtained.

Solubility and other tests with the original substance.

Besides the property of solubility in nitric acid, taking advantage of which was found the best method of isolating the succinic acid, the original substance is almost entirely soluble in hydrochloric acid, a small brownish residue being left, the succinic acid being precipitated on cooling the solution, providing the hydrochloric acid is not too dilute. The original substance is also soluble in sulphuric acid, with the exception of a small brownish residue, the succinic acid separating from this solution also on cooling. It is also soluble in both potassium and sodium hydrate. When boiled with solution of ammonia, a portion of the succinic acid is dissolved, forming succinate of ammonium, a more basic salt being left. The material acts in this way the same as ferric succinate does when boiled with ammonia.

When the original substance is boiled with carbonate of ammonium for a long time, filtered, ammonia added, to precipitate alumina, and evaporated to crystallization, with the occasional addition of ammonia as evaporation proceeds, good crystals of succinate of ammonium are obtained.

When the original substance is heated in a closed tube, succinic acid is not given off, the water being in fact quite neutral at a low temperature. When the temperature is raised, the water is found to be acid, but when dried in the tube, no solid residue is left, indicating that the trace of acid given off is volatile. Sufficient material was taken to give a few drops of this acid liquid, which gave the reaction of acetic acid with Fe_2Cl_6, but gave no precipitate with that reagent in a neutral solution, showing the absence of succinic acid.

When the powder is heated with bisulphate of potassium, the succinic acid sublimes, principally as the anhydride. When the

powder is directly treated with acids, the temperature rises considerably as it goes into solution.

When the powdered original substance is boiled for a long time in distilled water, practically nothing dissolves, nor is anything dissolved when it is boiled with alcohol. There appears to be no free acid in the material as determined by its insolubility in H_2O and C_2H_6O, and because it is not possible to obtain succinic acid when distilled in a tube without previously adding to the powder some bisulphate of potassium, or some suitable substance, so that the whole of the acid is present in combination with the base. Nitrogen was sought for in the original material but was found to be absent.

Determination of the presence of Acetic Acid.

When the original substance was first received, it had a sour and rather unpleasant odour, which diminished somewhat on keeping. In the systematic examination for acids, acetic acid was detected in minute quantities. To determine the presence of this acid, a portion of the original substance (between three and four grams.), was dissolved in sulphuric acid and distilled: the distillate was distinctly acid to test paper, had a slight odour of acetic acid, and gave the reactions for that acid with ferric chloride. Only a small quantity was present, as the distillate was readily neutralized with a very small quantity of an alkaline solution.

When the original material is dissolved in sulphuric acid, alcohol added, and the whole boiled, the odour of acetic ether is distinctly detected, especially on shaking as the liquid cools. When dissolved in soda and the solution acidified with sulphuric acid, alcohol added, and boiled, the odour of acetic ether is more readily obtained. The identification of acetic acid in the original substance is of some importance, as perhaps indicative of the mode of formation of the succinic acid by fermentation.

Composition of the original substance.

When heated in a closed tube much water is given off. A portion of the powder was heated at 100° C. to 110° C. for one

hour; the loss indicated 25·089 per cent. of water. Heated again for one hour from 110° C. to 120° C. no further loss was found to occur, neither when heated for one hour from 145° C. to 150° C. The powder was then ignited before the blowpipe until constant in weight, when it was found that 43·464 per cent. had been burnt away, leaving 31·447 per cent. of alumina; 100 per cent. of alumina being found, as stated above, in this ignited residue. As no other acid was detected other than succinic acid, with the exception of a trace of acetic acid, we may consider the composition to be

Organic matter as

Succinic acid	= 43·464	per cent.
Alumina	31·447	,,
Water	25·089	,,
	100·000	

From these figures we may look upon the material as a basic aluminium succinate, corresponding to a ferric succinate, and having the following formula:

$$Al_2 (C_4H_4O_4)_3 \; Al_2 O_3.$$

On ignition we get 2 Al_2O_3 and $C_{12}H_{12}O_6$ removed by burning, which, calculated out and allowing the same percentage of water as obtained by experiment as above, we have

Organic matter taken as ($C_{12}H_{12}O_6$)	= 44·484	per cent.
Alumina 2 (Al_2O_3)	30·427	,,
Water	25·089	,,
	100·000	

(We take the atomic weight of alumina as 27·3.)[1]

It would appear that in no previous investigations on natural salts of succinic acid found in vegetation has aluminium succinate

[1] The water present has been ignored in the formula, as we do not know in what form it is present, or whether it is an essential component of the material. The amount found indicates a quantity which, if combined, would represent between nine and ten molecules of water.

been discovered, although succinic acid in combination with lime has been detected as an exudation on the stem of the White Mulberry tree (*Morus alba*).[1] In another reference[2] to the presence of succinate of lime occurring in this exudation, the statement is made that the occurrence of succinic acid in the juices of a large number of herbs had long been known, but that it had not hiterto been found in liquids from trees. It was thought in this instance that the presence of a brown, humus-like substance, pointed to the fact that the succinic acid in this case was the product of a pathological process and not a physiological secretion.

The occurrence of succinic acid was considered to be due to a fermentation process, in consequence of which the malic acid occurring in the juices of the mulberry tree (*Gmelin*, 10,206) was converted into succinic acid, a metamorphosis which according to Fitz (*Ber.*, 12,481) takes place somewhat readily in schizomycetic fermentations.

The following formula represents the change

$$3\,C_4H_6O_5 = 2\,C_4H_6O_4 + C_2H_4O_2 + 2\,CO_2 + H_2O$$

(Malic Acid) (Succinic Acid) (Acetic Acid)

As we have found acetic acid in the original substance from *Grevillea robusta*, we suggest that the succinic acid in this case is also the effect of fermentation of malic acid, as this acid is of very common occurrence in plants, and is by fermentation readily converted into succinic acid. We have not yet succeeded in obtaining the fresh sap of *Grevillea robusta*, so that we are unable at present to state whether malic acid is present or not in the growing tree, and any more definite statement as to its mode of formation must be held over for the present. If malic acid be found to occur in the sap of *Grevillea robusta*, we think there can be but little doubt as to the origin of succinic acid contained in the present material. Not only is the material of interest from the presence of succinic acid, but that the base of the salt should be

---

[1] Gmelin, *Handbook of Chemistry*, Cavendish Soc., Vol. x., p. 108.

[2] *Journ. Chem. Soc.*, XLII., 602 (1882).

aluminium makes it doubly interesting, because of the rare occurrence in plants of this element.

The following extract is from a recent work.[1] "In spite of the wide distribution of clay in soil and in rocks, its chief constituent, aluminium, is confined in its occurrence to very few plants (lichens and club-mosses)." Another statement of the same kind is made by G. Bunge,[2] as follows, "Aluminium is one of the elements most frequently met with. . . . It is therefore remarkable that alumina has scarcely anything to do with the nutrition of living beings. It has been shown positively to exist in any noticeable quantity only in a few plants, especially in a few kinds of *Lycopodium*."[3]

We have also failed to obtain any evidence from other sources, of the presence of aluminium having been detected in material similar to which we now bring under your notice. That a salt of aluminium has been circulating through the vessels of this tree, *Grevillea robusta*, appears evident, but in what form it was originally deposited in the cavity of the wood it is now impossible to decide. The probability that it was as a malate, is indicated by the perfect solubility of aluminium malate in water, and the total insolubility of aluminium succinate in that liquid. We may also here point out that no inorganic acid could be detected in the portion taken for investigation.

In reference to the formation of artificial salts of aluminium succinate little information can be gathered. "According to Gehlin and Bucholz,[4] succinate of soda precipitates hydrochlorate of alumina (not however according to Bansdorff from very dilute solutions). Wenzel obtained by direct combinations an insoluble salt which crystallized in prisms." Chemical text books as a rule are silent as to the existence of any aluminium salt of succinic acid.

---

[1] *Treatise on the Physiology of Plants*—Dr. Paul Sorauer. (Weiss' translation 1895) page 36.

[2] *Physiological and Pathological Chemistry*, p. 27, 1890 (Kegan Paul).

[3] See also Text Book of Botany by Julius Sachs, 2nd Edition, p. 695.

[4] Gmelin, x., 108.

Attempt to prepare an artificial Aluminium Succinate.

When a neutralized solution of succinic acid is added to a solution of aluminium hydrate dissolved in hydrochloric acid, and neutralized with ammonia as much as possible without causing a precipitate, a dense white amorphous precipitate quickly forms. When this is thoroughly washed, dried at 120° – 125° C. until the weight is constant, then powdered and ignited, it is found that 66·4 per cent. of this dried residue is removed on burning, leaving 33·6 per cent. of alumina. This does not correspond to the theoretical quantity of either the normal or basic salt of aluminium succinate. When this dried powder is heated in a tube, before charring commences a liquid collects in the tube, which soon crystallizes into prisms of succinic acid, showing that succinic acid is given off in this way while the same experiment with the natural succinate of aluminium failed to give off succinic acid when thus heated as described above. The artificial salt also appears more harsh and brittle than the natural one.

The three following percentage results obtained by various observers[1] on succinic acid from various sources may be useful for comparison with our results.

D'Arcet.	Zwerger.	Piria.
C = 41·22	C = 40·62	C = 40·34
H = 5·33	H = 5·28	H = 5·22
O = 53·45	O = 54·10	O = 54·44

D'Arcet analysed the acid from Amber, Zwerger that from Wormwood, and Piria the acid obtained by fermenting an impure solution of Asparagin.

It is with pleasure that we place the results of our investigation before you, because it enables us to describe a salt of an organic acid rarely found except in small quantities, and forming a combination with aluminium that does not appear to have ever been found before in any tree, whether indigenous in Australia or not. Although it is quite possible that this is an accidental and rare

[1] Gmelin, *loc. cit.*

deposit in this particular tree, there appears to be no reason why other trees of this and other species may not be found to contain material identical in formation and composition, and all that appears to be required is careful search now that attention has been drawn to the matter.

On the AMOUNT of GOLD and SILVER in SEA-WATER.

By A. Liversidge, M.A., F.R.S.,

Professor of Chemistry, University of Sydney, N. S. Wales.

[*Read before the Royal Society of N. S. Wales, October 2, 1895.*]

In the following paper are given the results of some experiments made with the object of determining the amount of gold in the sea-water off the coast of New South Wales.

The only reference that I can find in Sydney libraries relating to the presonce of gold in sea-water, are those of Sonstadt,[1] which will be made use of later on in this paper, and a reference by Dr. T. Sterry Hunt[2] to a paper read before the American Association for the Advancement of Science in 1866, by Professor Wurtz, in which he expressed an opinion that gold would be found in sea-water, but I cannot trace Professor Wurtz's paper.

Then in 1894, Mr. E. C. C. Stanford, President of the Society of Chemical Industry, in his address to the members,[3] stated :— "The presence of gold has not been satisfactorily proved ; it was expected it might accumulate in the copper sheathing of ships, and Messrs. Muntz obliged me with specimens of old sheathing, both copper and muntz metal. Mr. Inglis, who kindly examined

---

[1] Chemical News, 1872, pp. 159, 160.

[2] Chemical and Geological Essays, London, 1879.

[3] Journ. Soc. Chem. Ind., XIII., July 31, 1894, p. 697.

these for me, found both gold and silver, but not in larger proportion than usual."

The results were, per ton :—

	Copper Sheathing.			Muntz Metal.		
	oz.	dwt.	grs.	oz.	dwt.	grs.
Gold ...	0	2	21	0	1	15
Silver	4	12	9	5	3	12

Professor Judd, F.R.S., informed me that a paper upon this subject was published in a Norwegian journal by Münster, about 1891, but I can find no reference to it in our Sydney libraries.

Sonstadt, in his paper on the presence of gold in sea-water gives various methods for the detection of the gold, and in a later letter to the Chemical News, March 11th, 1892, refers to his previous communication of 1872, and states that the amount of gold is "far less than one grain per ton."

His first process is as follows :—Two or three decigrammes of pure ferrous sulphate are dissolved in the water, which is acidulated by two or three drops of hydrochloric acid. The solution is heated in a *chemically clean* well glazed porcelain dish, over a small flame, so managed that the flame may touch the under part of the dish without causing ebullition. Under these circumstances a lustrous film of iron oxide forms in the dish, commencing from tho portion directly heated by the flame. The heat is continued, without boiling, until the sea-water is evaporated to about half, or so long as the film increases in extent and in lustre. The liquid is then poured off, the strongly adherent film is rinsed with a little water ; and then about 50 cc. of strong chlorine water is allowed to stand in the dish for an hour or two, after which it is slowly evaporated down (over the film) to a few drops, a drop of dilute hydrochloric acid being added towards the end of the evaporation. The liquid, which should be nearly colourless, is then poured into a test-glass containing a few drops of solution of stannous chloride, when, after a few minutes, the liquid takes a bluish or purplish tint, which may be exactly matched by a drop or two of a suitably diluted solution of gold added to a corresponding portion of tin-salt in another glass."

The sea-water first examined was collected from the coast at Coogee, away from any fresh water or other drainage. Eleven trials of this water were made with 200 cc. as recommended by Sonstadt, but no trace of a purple or even pink tint was obtained; but, with 600 cc. a faint amethyst tint was obtained after standing some time. As a rule, after adding the stannous chloride, a white or grey precipitate came down in the course of a few days, and this precipitate in many cases became pink, purple or slate coloured.

To check Sonstadt's method, various experiments were carried out. Gold chloride (from pure metal dissolved in chlorine water) was added to Coogee sea-water in the proportion of one grain of gold to the ton, and 200 cc. of this was treated by Sonstadt's process on March 19th, 1895, when a light brown precipitate was thrown down by the stannous chloride; on the 27th the precipitate was of a red colour below with a pale pink layer above; on the 3rd April the pink tint was more decided. Hence if allowed to stand for a few days, the test will detect in 200 cc. the presence of added gold in the proportion of one grain to the ton of sea-water, the gold originally present only being recognisable in 600 cc.

On December 11th, 1894, a litre of the Coogee sea-water was concentrated and the test applied, no trace of pink or purple appeared, but on February 8th, 1895, a slight brown sediment had formed, which may have been due to gold.

Next two litres were treated on December 28th, 1894, and allowed to stand until February 8th, 1895, when a faint pink tint was observable on the surface of the white precipitate. The second chlorine water extract of the film yielded a white precipitate which also had acquired a pink tint on February 8th.

On August 14th, 1895, two more samples each of two litres of Coogee water were tested. On the 15th the precipitates were brownish, the brownish tint seems to be due to the presence of gold. The contents of the two test tubes were mixed together, dried and scorified with 250 grains of assay lead free from gold, when a small bead of gold was obtained.

Sonstadt's second method was also tried, *i.e.*, with barium chloride as follows:—"From half a litre to a litre of sea-water should be taken for the experiment. As much solution of pure chloride of barium is added to the water as will give a grain of precipitate. A day or two should be allowed for the precipitate to settle. The precipitate is collected, dried, mixed with borax and lead, and the button of lead obtained before the blowpipe on charcoal is cupelled. The bead obtained is yellowish-white, of the same colour as an alloy of sixty parts of gold to forty of silver, or thereabout. For confirmation of the presence of gold the bead may be dissolved in a very small test tube, in a few drops of aqua regia, which is then evaporated, at a gentle heat, nearly to dryness. A few drops of pure hydrochloric acid are added, and the solution again evaporated, to destroy the excess of nitric acid. The solution is evaporated very nearly, but not quite, to dryness, a few drops of water are added, and the mixture warmed, and when the chloride of silver is settled, a drop of solution of stannous chloride is allowed to fall down the side of the tube into the liquid, when the characteristic gold reaction is obtained."

Sonstadt's barium chloride method was tried on sea water from off Jervis Bay as well as from the coast at Coogee, but the yield of gold was either much less than by the ferrous sulphate method (see further on) or no gold at all was obtained, even when two or more litres were used. Similar results were obtained from the use of stannous chloride and mercuric chloride together. Mercuric chloride alone and afterwards precipitated by hydrogen sulphide gave fairly good results. It was thought that the previous addition of sulphurous acid, oxalic acid and other reducing substances might increase the amount of gold obtained, but this was not found to be the case, on the contrary the yield was reduced.

As the result of a very large number of experiments with the film test upon gold chloride in distilled water and in sea-water, it was found that :—

1. All the gold is not carried down by the film—not even by repeating the process and obtaining a second film; a little gold still being obtainable by a third film.

2. Neither is all the gold extracted by one treatment of the film with chlorine water.

3. Some of the gold is left on the dish in evaporating the chlorine water solution.

4. Several days and even weeks were required, in many cases, for the colour reaction to appear.

Gold in Sea-water along the Coast of New South Wales.

Next a set of experiments was made upon water collected out at sea; twelve samples, two Winchester quarts of each, were kindly collected for me by Captain Hutton, of the N. S. Wales Government steamer "Thetis," by direction of Mr. C. W. Darley, then Engineer-in-Chief for Harbours and Rivers, to whom my thanks are due for the ready assistance he has given me in this and other similar matters. Prior to being sent out, the bottles were carefully cleaned, numbered and packed in cases (each holding two bottles) so as to ensure purity and prevent error, and each bottle was rinsed with sea-water when about to be filled.

Southern Sea-Waters.

In examining the southern sea-waters, in the first batch, a litre of each was treated and the characteristic reaction for gold obtained from Nos. 1, 2, 4, 5, and 6. In the next batch of two litres each, 1, 2, 3, and 5, showed the presence of gold: the films were treated a second time with chlorine water, when Nos. 3, 4 and 5, gave the gold reaction. In the third batch, Nos. 1, 2, 3, and 6 reacted for gold, and on a second treatment Nos. 3 and 6 again gave the reaction for gold. The details are as follows:—

No. 1, South—Collected 26th November, 1894, one mile east of South Head Lighthouse. Latitude 33° 43′ S.

Test No. 1. Upon one litre. $SnCl_2$ was added on December 11th, 1894, a white sediment was formed; this, on February 8th, 1895, had changed to a slate colour; the slate colour was probably due to the presence of gold.

Test No. 2. Upon two litres. December 22nd, 1894, the white precipitate on February 8th, 1895 showed a pinkish ring at upper

part evidently due to the presence of gold. The film from the ferrous sulphate was extracted a second time with Cl water, on December 31st; the solution became opalescent on the addition of the HCl and $SnCl_2$ and acquired a bluish tinge (probably due to gold) but by February 8th, this blue tint had disappeared and only a white sediment remained.

Test No. 3. Upon 1500 cc. June 12th, 1895. On the 21st June the white precipitate showed a pinkish layer at the top ½' deep, the pink colour was more decided on the 24th. On July 3rd and 4th it began to turn violet, and on July 7th, was of a distinct violet tint, and on the 10th July the upper part of the precipitate had darkened to a purple colour, which was doubtless due to the presence of gold.

No. 2, South—Collected 26th November, 1894, three miles off Bulli. Latitude about 34°.

Test No. 1. Gave a slight white sediment, on the 8th February this was yellowish with a dark reddish-brown ring.

Test No. 2. On two litres. Put up on December 22nd, 1894. On December 31st, the sediment was white; but had acquired a pinkish tinge on the surface by February 8th, 1895. The iron oxide film was extracted a second time with Cl water on December 31st, this gave a brownish coloured solution and a white precipitate, which had not changed by February 8th.

Test No. 3. Upon 1500 cc. June 12th, 1895. On July 6th there was a slight red tint on the sediment, and on July 10th this had become brown.

No. 3, South—Collected 27th November, 1894, five miles from Black Head, Shoalhaven Bight. Latitude about 34°.

Test No. 1. Upon one litre. Clear, bluish tinge, sediment slightly coloured.

Test No. 2. On two litres. A slight amethyst tint within three minutes after adding the $SnCl_2$. On February 8th, 1895, the sediment was bluish below with the pink colour above unchanged.

The second Cl water extract of the film, on adding the $SnCl_2$ became opalescent with a faint amethyst tinge; on February 8th, 1895, the sediment was white with light reddish-brown ring.

Test No. 3. 1900 cc. June 21st, 1895. A buff sediment with a pinkish tint at top; on the 24th the pink tint was deeper, a pale violet on July 3rd, and on the 6th July had become a full violet; on the 10th July this had become purple—the buff below remaining unchanged.

No. 4, South—Collected 27th November, 1894, from one mile off Cape St. George Lighthouse, Jervis Bay. Latitude about 35° S.

Test No. 1. Upon one litre. December 11th, 1894. After standing five hours the solution was clear with a bluish tinge; sediment slightly coloured. On 8th February, 1895, the white sediment was marked by a reddish ring.

Test No. 2. Two litres, on 22nd December, 1894. No colour on the 29th nor on the 8th February, 1895. Nor from the second Cl water extract; afterwards yielded a bluish tinge with pinkish colour to sediment.

Test No. 3. 1900 cc. 21st June, 1895. A bluish tinge on top of white sediment observed 5th July, 1895.

No. 5, South—Collected 27th November, 1894, from two miles off Brush Island. Latitude about 35° 5′ S.

Test No. 1. Upon one litre, 11th December, 1894. Clear bluish tinge; on 8th February, 1895, the white sediment showed a bright pink ring.

Test No. 2. Gave no indication of gold, neither did the second Cl water extract.

Test No. 3. 1300 cc., 21st June, 1895. On addition of the stannous chloride this gave a bluish tinge; on July 10th the white sediment was almost black at the base.

No. 6, South—Collected 28th November, 1894. From twenty-seven miles off Broulee near Moruya. Lat. about 36° 5′ S.

Test No. 1. Upon one litre, 11th December, 1894. No colour nntil 8th February, 1895, when the light brown sediment showed a reddish ring.

Test No. 2. Upon two litres. Amethyst tinge. Second extract with Cl water gave a bluish tinge and the sediment had a slight pink colouration.

Test No. 3. 1225 cc., 21st June 1895. On the 24th June, the white sediment showed a pink tinge at top $\frac{1}{16}''$ deep; on July 10th 1895, the sediment was pale brown with an onyx-like layer near the top, with faint purple tinge.

On April 3rd, 1895, the precipitate in each test tube of the first batch of southern waters had changed to a dirty, almost black, colour, *i.e*,, after an interval of nearly four months from the initiation of the experiment, viz., from 18th December 1894 to 3rd April 1895.

It was noticed, in some instances, that after long standing the pink or violet tint gradually faded, especially on the side exposed to the brighter light of the window, in some cases the colour disappeared totally.

Northern Sea-Waters.

No. 1. Collected February 19th, 1895, about one and a half miles off Sandy Point, Richmond River, Lat. about 28° S.

No. 2. Collected at North Solitary, Lat. about 29° S., February 19th, a strong southerly current.

No. 3. From about four miles off Smoky Cape, Lat. about 30°, on February 20th.

No. 4. From two miles off Tacking Point, Lat. about 31° 30′, February 20th.

No. 5. From two miles off Cape Hawke, Lat. about 32° 2′, February 20th.

No. 6. About five miles off Port Stephens, Lat. about 33°, February 20th.

All six samples of northern sea-waters also gave the reaction for gold; the details are omitted for brevity. As in the case of the southern samples, some gave the reaction readily, others required from one to several weeks. I should not however, like to say that this is a sufficient indication of some being richer than others, for the test appears to be wanting in precision.

Quantitative Tests.

Unfortunately all the samples had been used up in making qualitative tests for gold, but, in default of more water, the chlorine-water solutions and precipitates yielded by the stannous chloride from each batch of tests were mixed together and evaporated to dryness and then scorified and cupelled so as to determine the amount of gold. The assays were not done separately on each test, as it was thought that the gold beads, if any, would be too small to weigh.

Southern Sea-waters.—The first batch of tests, Nos. 1 to 6, *i.e.*, the extracts from six litres, gave ·003 grain of gold, *i.e.*, ·508 grain of gold per ton, or ·38 grain per cubic yard, or ·032 mgm. per litre.

Second batch.—The precipitate from twelve litres used for the second set of tests gave ·009 grain, *i.e.*, ·76 grain of gold per ton, or ·57 grain per cubic yard, or ·048 mgm. per litre. The film was treated twice with chlorine water, and the two extracts added together.

Third batch.—9·025 litres gave ·0069 grain of gold, *i.e.*, 1·09 grain per ton, or ·58 grain per cubic yard, or ·049 mgm. per litre.

Northern Sea-Waters.

8·100 litres gave ·0060 grain of gold equal to ·75 grain per ton, or ·56 grain per cubic yard, or ·048 mgm. per litre.

In calculating the amount of gold per ton or cubic yard, the specific gravity was in each case corrected to 1·026, *i.e.*, the mean results obtained by the "Challenger" Expedition, corrected to 15·5° C. for sea-water off the coast of New South Wales.

Before proceeding with further determinations of gold in sea-water, experiments were made to ascertain what loss of gold was sustained in the case of solutions containing known quantities of gold.

Experiments with Distilled Water and Added Gold.

The following experiments were made to ascertain whether small quantities of gold in dilute solution could be recovered by treatment with ferrous sulphate and other reagents. After adding the ferrous sulphate the solution was exposed in large new shallow photographer's developing dishes for some days, so that the ferrous sulphate might be slowly oxidised and precipitated; in some cases glass cylinders were used and air blown through the solution. To complete the precipitation ammonia was added, the precipitate collected, washed, dried, scorified, and cupelled.

From the following results it will be seen that there was but little loss in some cases, but a good deal in others, partly due to imperfect precipitation by the ferrous sulphate, and partly to the loss during cupellation. In most cases the treatment with ferrous sulphate, oxidation and precipitation was repeated upon the filtrate from the first precipitate.

1000 cc. distilled water and 1 cc. of ·01% $AuCl_3$ solution = ·00154 grains gold.

(1) Treated with ·5 gram. $FeSO_4$ and NH_3 yielded ·0015 gr.
(2) Filtrate treated with ·25 gram. $FeSO_4$ & NH_3 „ ·0000 „

Gold = ·0015 „

1000 cc. distilled water (containing 30 grammes NaCl) and 1 cc. of ·01% $AuCl_3$ solution = ·0015 grain of gold.

(1) Treated with ·5 gram. $FeSO_4$ and NH_3 yielded ·0011 gr.
(2) Filtrate treated with ·25 gram. $FeSO_4$ & NH_3 „ ·0000 „

Gold = ·0011 „

i.e., a loss of ·0004 grain gold or 26·6% The presence of the NaCl seems to increase the loss of gold.

1000 cc. distilled water and 100 cc. of ·01% $AuCl_3$ solution = ·1543 grain gold.

(1) Treated with 1 gramme $FeSO_4$ and NH_3 yielded ·1253 gr.
(2) Filtrate treated with ·5 gram. $FeSO_4$ & NH_3 ,, ·0010 ,,

·1263 ,,

i.e., a loss of ·0280 grain gold or 18·14%.

1000 cc. distilled water and 100 cc. of ·01% $AuCl_3$ solution = ·1543 grs. gold.

(1) Treated with 1 gramme $FeSO_4$ and NH_3 yielded ·1327 gr.
(2) Filtrate treated with ·5 gram. $FeSO_4$ & NH_3 ,, ·0010 ,,

·1337 ,,

i.e., a loss of ·0206 grain gold or 13·35%.

Experiments with Sea-Water and Added Gold.

1000 cc. Coogee sea-water and 100 cc. of ·01% $AuCl_3$ solution = ·1543 grains of added gold.

(1) Treated with ·5 gramme $FeSO_4$ and NH_3 yielded ·1430 gr.
(2) Filtrate treated with ·25 gram. $FeSO_4$ & NH_3 ,, ·0020 ,,

·1450 ,,

i.e., a loss of ·0093 grain gold or 6·027%.

1000 cc. Coogee sea-water and 100 cc. of ·01% $AuCl_3$ solution = ·1543 grains gold.

(1) Treated with ·5 gramme $FeSO_4$ and NH_3 yielded ·1415 gr.
(2) Filtrate treated with ·25 gram. $FeSO_4$ & NH_3 ,, ·0020 ,,

·1435 ,,

i.e., a loss of ·0108 grain gold or 7%.

500 cc. Coogee sea-water and 10 cc. of ·01% $AuCl_3$ solution = ·0154 grains gold.

(1) Treated with 1 gramme $FeSO_4$ and NH_3 yielded ·0095 gr.
(2) Filtrate treated with ·5 gram. $FeSO_4$ & NH_3 ,, ·0000 ,,

·0095 ,,

i.e., a loss of ·0059 grain gold or 38·31%.

500 cc. Coogee sea-water and 10 cc. of ·01% $AuCl_3$ solution = ·0154 grains gold.

(1) Treated with barium chloride yielded ·0013 gr.
(2) Filtrate treated with 1 gram. $FeSO_4$ & NH_3 „ ·0069 „

·0082 „

i.e., a loss of ·0072 grain gold or 46·75%.

2000 cc. Coogee sea-water and 50 cc. of ·01% $AuCl_3$ solution = ·0771 grains gold

(1) Treated with 1 gramme lead acetate in acetic acid and precipitated by sheet zinc, yielded ·0708 gr.
(2) Filtrate treated with 1 gram. $FeSO_4$ & NH_3 „ ·0000 „

·0708 „

i.e., a loss of ·0063 grain gold or 8·17%.

2000 cc. Jervis Bay sea-water and 25 cc. of ·01% $AuCl_3$ solution = ·0385 grains gold.

(1) Treated with 1 gramme lead acetate and precipitated by sheet zinc, yielded ·0235 gr.
(2) Filtrate treated with 1 gram. $FeSO_4$ & NH_3 „ ·0016 „

·0251 „

i.e., a loss of ·0134 grain gold or 34·8%.

It must be borne in mind that to the loss of gold sustained in the above experiments should be added the amount of gold also present in the sea-water. The smallest loss seems to be sustained when the gold is precipitated by ferrous sulphate and ammonia, but even that process is far from satisfactory.

Additional determinations of gold in sea-water from Coogee.

2000 cc. treated with ·5 gram. $FeSO_4$ and NH_3 yielded ·0015 gr. = 0·76 grains per ton.

(1) 9000 cc. treated with 2·5 gram. of $FeSO_4$, air blown through and NH_3 added, yielded ·0028 gr. = 0·31 gr. per ton
(2) Filtrate treated with 1 gram. $FeSO_4$ and NH_3 added yielded ·0035 gr. = 0·39 gr. „

Total ·0063 gr. = 0·7 gr. „

(1) 2000 cc. treated with 1 gram. lead acetate and precipitated by sheet zinc, yielded ·0003 gr. = 0·152 gr. ,,

(2) Filtrate treated with 1 gram. $FeSO_4$ and NH_3 yielded ·0002 gr. = 0·101 gr. ,,

Total ·0005 gr. = 0·253 gr. ,,

It was found when large quantities of Coogee sea-water, *e.g.*, forty-five litres were treated with from 1·5 to 5 grammes of ferrous sulphate, followed by exposure for oxidation, scorification, and cupellation, that the amount of gold obtained was very much less in proportion than that yielded by treating one or two litres.

Several trials were made, a larger quantity of ferrous sulphate would doubtless have given results similar to those obtained from two litres; but I have not had time to repeat the experiments with large quantities of ferrous sulphate—as dealing with large quantities is slow and laborious with ordinary laboratory appliances.

The inside of the thirty-six gallon cask which had contained the Coogee sea-water was scraped: but very imperfectly, about two ounces of scrapings obtained, they were incinerated, scorified and cupelled when a bead was obtained containing—

·0070 grain of silver = 5 dwt. 5·43 gr. per ton
·0017 ,, gold = 1 ,, 6·46 ,,

Only a part of the barrel was scraped, and that not deeply, but the above results are quite sufficient to show that the gold and silver in sea-water are precipitated by the wood &c., hence water which has been kept in wooden vessels does not yield the full amount of these metals, and the very small amount of silver found in sea-water by Malaguti may have been due to his keeping the sea-water in a wooden cistern.

All my experiments were made upon sea-water collected and kept in glass vessels, with the exception of the later ones on Coogee water, which had been kept in the barrel.

Gold in Sea-water collected off Jervis Bay.

(1) 2000 cc. treated with 1 gramme of $FeSO_4$ yielded	·0001 gr.	= 0·05 gr. per ton
(2) Filtrate treated with ·5 gramme $FeSO_4$ and NH_3 yielded	·0002 gr.	= 0·101 „
Total	·0003	0·151 „

(1) 2000 cc. treated with 1 gramme lead acetate and precipitated by sheet zinc, yielded	·0020 gr.	= 1·016 gr. per ton
(2) Filtrate treated with 1 gramme $FeSO_4$ and NH_3 yielded	·0000 gr.	= 0·000 „
Total	·0020	1·016

1000 cc. treated with chlorine, and then with 5 cc carbon disulphide, to dissolve out any iodine or bromine which might have been set free; decanted 1 gramme lead acetate added and precipitated by zinc, yielded ·0005 gr. = 0·508 gr. per ton.

1000 cc. treated with two grammes mercuric chloride for four days and then precipitated by H_2S, yielded ·508 gr. gold per ton.

Experiments with other processes are now being carried out; but as they are not complete the results are deferred for a later paper.

To test the ordinary Sydney water supply, collected over a sandstone area, 124 lbs. weight of the laboratory tap water was tested for silver and gold by adding 100 cc. sulphurous acid, five grammes ferrous sulphate and allowing to oxidise for several days, the iron hydroxide was then precipitated by ammonia—scorified and cupelled—but neither gold nor silver was found.

The amount of gold obtained from sea-waters in the foregoing experiments must necessarily be less than the total amount of gold present in the water, since it was found that known quantities of gold chloride solution added to distilled and sea-waters and then estimated by precipitation, scorification and cupella-

tion nearly always showed a loss, and sometimes a very considerable one.

All the above evidence is in favour of gold being present in sea-water off the New South Wales coast in the proportion of about ·5 to 1 grain per ton, or in round numbers from 130 to 260 tons of gold per cubic mile. This of course means an enormous amount for the whole of the ocean, the cubic contents of which used to be put down at 400,000,000 cubic miles, and if the gold be uniformly present at the rate of 1 grain per ton the total amount would be over 100,000,000,000 tons of gold; a later estimate is 308,710,679 cubic miles, this even would mean over 75,000,000,000 tons of gold. But at the present day it would probably not pay to extract the gold by itself, although it might as a bye product in the manufacture of salt, bromine, &c. The enormous amount of gold in the sea is, however, probably very small in comparison with the amount scattered through sedimentary and crystallised rocks, *i.e.*, apart from gold in veins and other deposits.

Silver in Sea-Water.

All the sea waters gave some silver, usually from one to two grains per ton, but I consider the scorification and cupellation process lacking in the necessary precision for the exact determination of silver in such minute quantities as it exists in sea-water, I have therefore omitted all the determinations of silver from this paper, but I may publish them later on with the results of other experiments now in hand.

Malaguti estimated the amount of silver in sea-water at ·001 gramme per 100 kilos of sea-water, or at only ·15 grains per ton; but I have quoted him more fully in the next paper in this volume "*On the removal of Gold and Silver from Sea-water by Muntz Metal Sheathing.*"

The REMOVAL of SILVER and GOLD from SEA-WATER by MUNTZ METAL SHEATHING.

By A. Liversidge, M.A., F.R.S.,
Professor of Chemistry, University of Sydney, N. S. Wales.

[*Read before the Royal Society of N. S. Wales, October 2, 1895.*]

Amongst the writers upon the occurrence of *silver* in sea-water, we have Malaguti, Durocher, and Sarzeaud in 1850, Fred. Field in 1856, and Forchhammer in 1865, and as it is difficult for many, especially in this part of the world, to obtain or see the originals, I quote the following extracts from their papers. None of them make any mention of the presence of gold in sea-water or of its removal.

The following extract is from a paper by Messrs. Malaguti, Durocher et Sarzeaud, entitled—*Recherches sur la présence du plomb, du cuivre et de l'argent dans l'eau de la mer et sur l'existence de ce dernier métal dans les plantes et les êtres organiques.*[1]

"*Estimation of silver in sea-water.*—A considerable quantity of sea-water was taken from off the coast of St. Malo, a few leagues from land, and preserved during the course of the experiments in a wooden cistern, from which it was taken out as occasion required, in glass vessels. The presence of silver in this water was first demonstrated by the sulphuretted hydrogen process above described: but in order to obtain a more exact estimation of the quantity, fifty litres of the water were evaporated to dryness, and the crude salt thence obtained, weighing 1,300 grammes, was divided into thirteen equal portions, and each portion fused with thirty grammes of pure litharge and 1·13 grms. of lamp-black. This mixture, which was made very intimate by long trituration in a porcelain mortar, was gradually heated to dull redness in a

[1] Journ. Chem. Soc. III., 1851, pp. 69-70, extracted from Ann. Ch. Phys. (3) XXVIII., 129.

crucible, and maintained at that temperature for fifteen or twenty minutes; the heat was then gradually raised till the mixture fused, and afterwards increased to whiteness; as soon as that temperature was attained, the crucible was withdrawn from the fire. Thirteen operations of this kind yielded 124 grams. of lead, and the silver contained in this was found by cupellation (deducting that which was yielded by the lead alone, in a test experiment) to amount to 0·0005 grm. Now, as this demi-milligramme of silver was extracted from fifty litres of sea-water, it follows that one hundred litres—or for simplicity, say one hundred kilogrammes of sea-water –contain one milligramme; hence the proportion of salt in sea-water is, approximately, one part in 100,000,000, so that a cubic myriametre of sea-water contains 1,000 kilogrammes, or a cubic mile (English) contains about 2¾lbs.[1] avoirdupois. This estimation must be regarded as a minimum; for all the preceding operations are attended with slight loss."

In the same paper, they refer to the presence of silver in certain fuci, amounting to $\frac{1}{100,000}$: in various trees such as oak, birch, beech and apple, also in the blood of an ox and the vegetables upon which it had been fed. They also found it in rock salt and in coal, but as the coal contained pyrites, they do not attach the same importance to its presence in this case.

"*On the existence of silver in sea-water*, by Frederick Field, F.C.S.[2] He examined the sheathings of certain traders as follows:—"Ana Guimaraens," a Chilian vessel, trading up and down the South Pacific for seven years. Yellow metal from the bottom of vessel; 5,000 grains were dissolved in pure nitric acid and the solution diluted; a few drops of hydrochloric acid were added and the precipitate allowed to stand for three days. A large

[1] The amount obtained by Malaguti viz.: ·0005 gramme of silver from 50 litres of sea-water represents over 40 tons of silver per cubic mile, not 2¾lbs. only, as given in the above translation. Malaguti is not responsible for this error, as it does not occur in the original, where however, there is also a great error, since ·0005 g. for 50 litres is said to be equal to 1000 kilos of silver per cubic myriametre instead of to 10,000,000 kilos.

[2] Proc. Royal Society London, Vol. VIII., 1856-7, p. 292.

quantity of white insoluble matter had collected by that time at the bottom of the beaker. This was filtered off, dried, and fused with 100 grs. pure litharge, and suitable proportions of bitartrate of potash and carbonate of soda, the ashes of the filter also being added. The resulting button of lead was subsequently cupelled and yielded 2·01 grs. silver, or 1 lb. 1 oz. 2 dwts. 15 grs. troy per ton. A piece of new yellow metal with which the vessel was being repaired, yielded only 0 oz. 18 dwts. to the ton.

"Nina," a brig just arrived in the Pacific from England. The experiments were performed as before with results:—1,700 grs. of the new metal kept in the cabin for possible repairs gave ·051 grs. = 003% = 19 dwts. 14 grs. per ton.; 1,700 grs. from the hull, where it had been three years, gave ·400 grs. = ·023% = 7 ozs. 13 dwt. 1 gr. per ton.

The amount of silver in the new metal for the "Nina" and "Ana Guimaraens" are unusually low, being both under one ounce per ton.

"Bergman," a piece from the hull gave 5 ozs. 16 dwts. 18 grs. per ton; a piece from the cabin gave 4 ozs. 6 dwts. 12 grs. per ton.

"Parga," 200 grs from a piece from the hull gave ·072 grain, and a piece of fresh metal ·050.

"Grasmere," only coppered a few months; 610 grains from hull gave ·075 and from the cabin ·072 grain.

Mr. Field remarks:—"It will be observed that the amount of silver in the above specimens of fresh metal is very high, and it is probable that most of these are merely the re-rolling of masses of metal melted down from old sheathing, and have derived the greater part of their silver from the sea on former occasions. It is well known that the copper used in the manufacture of yellow metal is very pure, containing two or three dwts. of silver per ton, frequently not so much, and silver is very seldom associated with the other constituent, zinc. In order to arrive at more certain results, however, I have granulated some very pure copper, reserving some in a glass stoppered bottle, and suspended the remainder

(about ten ounces) in a wooden box perforated on all sides, a few feet under the surface of the Pacific Ocean. When occasion offers the box is towed by a line at the stern of a vessel which is trading up and down the coast of Chili. It is almost too soon to expect any decisive results at present, but in a few months I hope to be enabled to send both the original copper, and that which has been exposed to the action of the sea."

I do not know whether Mr. Field ever published the results, but I have not come across any reference to them.

"*On the composition of sea-water in different parts of the ocean*, by Professor Georg Forchhammer.[1]—"*Silver*.—Malaguti first showed that silver occurs in the organisms of the sea; I have subsequently proved it to exist in a coral, a *Pocillopora*, and several chemists have since tried to prove that silver is precipitated by the galvanic current between the copper coating of a vessel and sea-water. If the last determination is confirmed, the existence of silver in sea-water is proved by direct experiment. From the *Pocillopora alcicornis* I have separated it in the following manner:—I dissolved the coral in muriatic acid, precipitated the solution by hydrosulphate of ammonia, and dissolved the precipitate, which consisted of sulphurets, of phosphate of lime, and fluoride of calcium, in very weak cold muriatic acid, which left the sulphurets of silver, lead, and copper probably mixed with those of cobalt and nickel. These sulphurets were separated from the solution, evaporated to dryness with a little nitric acid, to which were added a few drops of muriatic acid, and dissolved in water, which leaves sulphate of lead and chloride of silver undissolved. When the filter which contained the latter substances is burnt, the silver is reduced to metal; a solution of pure soda will dissolve the sulphate of lead and leave the silver, which, when dissolved in nitric acid, can be tested with muriatic acid. I obtained from *Pocillopora alcicornis* about $\frac{1}{3,000,000}$ or from a solid cubic foot of the coral about half a grain of silver."

[1] Phil. Transactions, 1865, pp. 211, 212.

Old Muntz Metal Sheathings.

Mr. Cecil W. Darley, late Engineer-in-Chief for Harbours and Rivers, was kind enough to obtain for me some pieces of old muntz metal sheathing from the piles of wharfs undergoing repair. These were examined for gold and silver with the results given below.

The method used for assaying was as follows :—In each case 2,000 grains, except where otherwise stated, of the sheathing in strips were dissolved in 1500 cc. of pure nitric acid (1 to 3 aq.), free from chlorine. After being cut into strips, the sheathings were boiled in water, beaten, and scrubbed with a brass scratch brush so as to get rid of the dirt and scale as far as possible; this probably also had the effect of removing part of the portion richest in gold and silver, as the assays of the separated scale show that it contains more of the precious metals than the body of the sheathing. In most cases, the residue was grey and contained much lead. The clear nitric acid solution was decanted and filtered off and some sodium chloride solution added to ensure the precipitation of all the silver ; in the few cases where there was an additional precipitate of silver chloride, this was added to the gold and other insoluble matter on the filter. The solutions varied from green to blue. The filter and residue were dried, wrapped in special assay lead free from gold, scorified, cupelled and checked in the usual way. In certain cases, the sheathing was dissolved in sulphuric acid, (but, as the solution took place more rapidly in nitric acid, the latter was preferred) when a yellow substance was generally found on the clock glasses used for covering the beakers : this was found to consist of sulphur containing a little copper, the latter carried up mechanically by spirting : the sulphur was doubtless derived from the sulphuric acid by part of the acid being reduced by the nascent hydrogen given off from the zinc of the alloy or more probably by the reaction between the hydrogen sulphide and sulphur dioxide evolved.

Sheathing from an old trader, purchased in Sydney about 1874. The solution was made in sulphuric acid as already mentioned.

Silver.	*Gold.*
4 ozs. 15 dwts. 9·2 grs. per ton.	1 dwt. 2·4 grs. per ton.

This sheathing was referred to in a paper on the "Origin of Gold Nuggets,"[1] and was remarkable for containing a good deal of iodine, but none of the other sheathings, since examined, have yielded any iodine.

(*a*) From pile in Mr. Thomas Nobbs' wharf at Ballina, N.S. Wales, between high and low water mark. Exposed four years to sea water. Corroded but not so deeply as (*d*).

Silver.	*Gold.*
2000 grains gave 6 ozs. 9 dwt. 8 grs. per ton.	11·8 grs. per ton.

Metallic copper 64%.

(*b*) From longitudinal brace in Ballina Government wharf, N. S. Wales, between high and low water mark. Exposed six years to sea water.

Silver.	*Gold.*
2000 grains gave 2 ozs. 2 dwt. 22 grs. per ton.	4·7 grs. per ton.

Metallic copper 64%.

(*c*) From piles in Government wharf, Ballina, N. S. Wales, between high and low water mark. Exposed six years to sea water. Not much corroded and fairly thick metal.

Silver.	*Gold.*
2000 grains gave 3 ozs. 19 dwt. 5 grs.	19·6 grs. per ton.
2158 grains gave 4 ozs. 5 dwt. 14 grs.	1 dwt. 7 grs. ,,
2394 grains gave 4 ozs. 12 dwt. 0 grs.	1 dwt. 22 grs. ,,

Metallic copper 60·3%.

In the last, the solution was made with sulphuric acid.

(*d*) From the pile of Mr. Fenwick's wharf, Ballina, N. S. Wales, wholly submerged for thirteen years in sea-water.

So brittle as to break readily between the fingers, with a copper coloured granular fracture, hence in parts most of the zinc has

[1] Journ. Roy. Soc. N. S. Wales, 1893, p. 331.

apparently been dissolved out. The sheet is much corroded, and very thin on the edge, stained green and brown.

Heated in a tube it emits a "sea-shore" odour, and gives off water which has an acid reaction ; it also yields a fusible sublimate of tarry matter mixed with sulphur. Dissolves entirely in nitric acid, one to three water. The metal when boiled with water, yields a solution containing chlorine and a trace of sulphuric acid from sulphates. After boiling with pure dilute sulphuric acid, the metal acquires a copper-red colour and shows a granular or crystalline structure ; a black residue is left, and the solution, on cooling, deposits crystals of lead chloride.

	Silver.	*Gold.*
2000 grains gave	3 ozs. 14 dwt. 21 grs.	9 grs. per ton.

Metallic copper 62·2%.

The scale, first treated with nitric acid.

227 grains gave	1 oz. 10 dwt. 4·4 grs.	15 dwt. 19·5 grs. „

(*e*) From Irvington, N. S. Wales. Exposed to fresh water; very little corroded.

	Silver.	*Gold.*
2000 grains gave	5 ozs. 6 dwt. 8 grs.	19·6 grs. per ton.

Metallic copper 62·3%.

The scale, extracted with nitric acid and the residue scorified and cupelled—

70 grains gave 1 oz. 7 dwt. 23·10 grs. 9 dwt. 8·22 grs. per ton.

(*f*) From Coraki, N. S. Wales. Exposed to brackish water.

	Silver.	*Gold.*
2000 grains gave	5 ozs. 6 dwt. 12 grs.	13 grs. per ton.

Metallic copper 63·5%.

(*g*) From Newcastle and Hunter River Steamship Company's upper wharf at Morpeth, N. S. Wales. Supposed to have been on piles about four years, exposed to brackish water. Very little corroded.

	Silver.	*Gold.*
2000 grains gave	5 ozs. 15 dwt. 20 grs.	11 grs. per ton.

Metallic copper 62·5%.

(*h*) From Newcastle and Hunter River Steamship Company's upper wharf at Morpeth, N. S. Wales. Supposed to have been on piles four years in brackish water. Clean, *i.e.*, not coated with green or red scale as usual, and but slightly corroded.

	Silver.	*Gold.*
2000 grains gave	5 ozs. 7 dwt.	10·2 grs. per ton.

Metallic copper 62·4%.

(*i*) From front of pile, No. 1 jetty, (between Nos. 4 and 5 cranes) Bullock Island wharf, N. S. Wales. Submerged about twenty years in sea-water. Green, somewhat corroded, but still **fairly thick and solid.**

	Silver.	*Gold.*
2000 grains gave	4 ozs. 1 dwt. 16 grs.	16·5 grs. per ton.

Metallic copper 61·6%.

(*j*) From Circular Quay, Sydney, N. S. Wales. Submerged about forty years. The old Tank Stream, now a sewer, has its outfall at Circular Quay, but I do not know how near to the samples of sheathing examined. Much corroded, the sheets being **eaten into large holes.**

	Silver.	*Gold.*
4000 grs. gave	7 oz. 19 dwt. 18 grs.	6·5 gr. per ton.

The following were treated with sulphuric acid :—

	Silver.	*Gold.*
2000 grs. gave	3 oz. 17 dwt. 8·4 grs.	11·90 gr. per ton.
4000 „	4 oz. 15 dwt. 8·5 grs.	8·62 gr. „

Metallic copper 61·6 . Metallic zinc in the much corroded parts = 34·68 , in the thicker parts 35·49 .

The Scale, extracted first with 500 cc. of nitric acid (1 - 3 aq.):—

	Silver.				*Gold.*			
	oz.	dwt.	grs.		oz.	dwt.	grs.	
300 grains gave	4	16	11	per ton.	0	4	18·5	per ton.
300 „	5	12	19·1	„	0	4	18·5	„
260 „	7	10	16·5	„	0	6	1·8	„
150 „	6	7	4	„	0	7	18·6	„
150 „	12	2	18·9	„	0	5	15·2	„
„	7	10	16·8	„	0	10	10·8	„
Average	7	6	18		0	6	13·9	

The loose easily removed scale of a second lot of sheathing from Circular Quay was assayed, but was first roasted and then extracted with pure sulphuric acid before scorification and cupellation. As will be seen from the results, this scale was richer in silver, the gold was very irregular, and was found to contain platinum derived from the H_2SO_4, hence the amounts are omitted. The H_2SO_4 had probably taken it up from the platinum stills used in concentrating it.

Silver.

			oz.	dwt.	grs.	
100	grains	gave	25	12	5·12	per ton.
100	,,		22	17	19·84	,,
200	,,		23	2	5·6	,,
200	,,		21	9	13·6	,,
100	,,		16	1	10·56	,,
100	,,		18	11	10·08	,,

(*k*) Mr. Hickson forwarded to me a supply of sheathing from the square piles of the original Queen's Wharf, Newcastle, where it had been exposed for probably thirty-five years.

The outer scale, which could be removed by a spatula, was dissolved as usual in pure nitric acid and the residue scorified and cupelled. Two assays of 150 grains each gave

2 oz. 8 dwt. 18 grs. per ton of silver, but no gold
1 oz. 3 dwt. 11 grs. ,, ,, ,,

Then 200 grains of the hard and adherent scale under this, with scrapings of the metal itself gave—

6 oz. 10 dwt. 16 grs. per ton of silver.
6 ,, 1 ,, 12·4 ,, ,,

Next the metal sheathing itself, dissolved in sulphuric acid, after removal of the above two scrapings, gave—

6 oz. 8 dwt. 15·3 grs. of silver per ton.
7 ,, 4 ,, 12·4 ,, ,,

The amounts of gold are omitted since the beads were found to contain platinum.

(*l*) Mr. Hickson also forwarded some of the old sheathing from the bottom of the lighter "Topsy" which was built in 1881, and had been employed at Newcastle.

Two assays were made of the scale from this, and first treated with nitric acid as usual ; unfortunately there were only sufficient for seventy five grains for each assay. The results obtained were :

Silver.	*Gold.*
2 oz. 3 dwt. 13·2 grs.	0 oz. 1 dwt. 17·8 grs. per ton.
1 „ 5 „ 6·3 „	0 „ 0 0 20·9 „

The metal dissolved in sulphuric acid yielded—

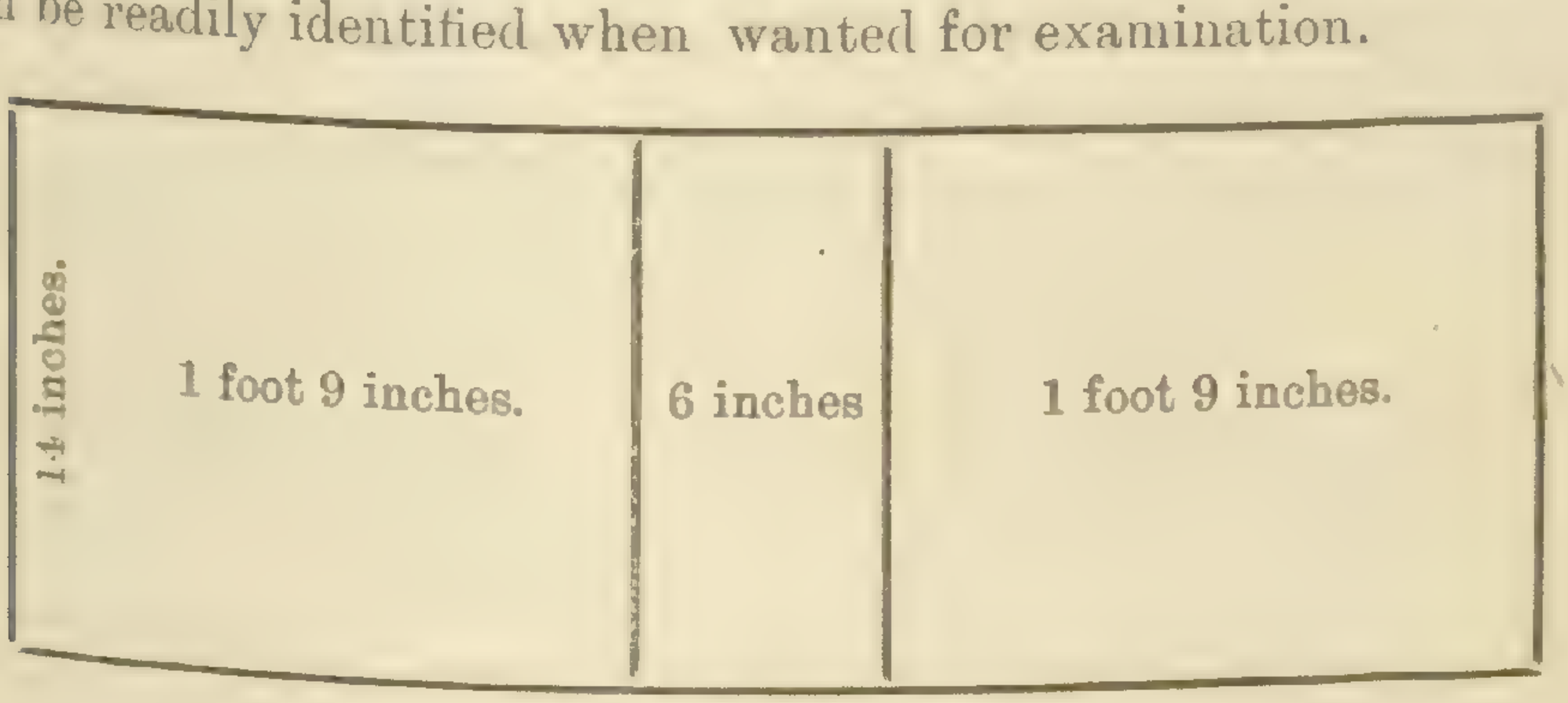
5 oz. 4 dwt. 9·5 grs. silver per ton.

5 „ 14 „ 12·7 „ „

The gold is omitted on account of its containing platinum ; but an assay on 1000 grains dissolved in nitric acid gave 5 oz. 5 dwt. 12 grs. of silver and 15·68 grains of gold per ton.

Experiments with New Muntz Metal.

Mr. Darley was also kind enough to have plates of muntz metal placed for me on the piles of certain wharves, according to the following list, so that they might be examined from time to time, to ascertain whether they really do become richer in gold and silver ; each plate was divided as shown by the accompanying diagram, the central strip, 6″ × 14″ was sent to me for assay, and the two other pieces 21″ × 14″, were placed on a Southern and Northern wharf respectively, numbered and marked so that they can be readily identified when wanted for examination.



4 feet by 14 inches.

The assays of the new muntz metal, before exposure to the sea-water, were made for me in the University Laboratory by Mr. S. J. Speak, A.R.S.M., lecturer in Metallurgy and Demonstrator in Chemistry, now of Johannesberg.

They were dissolved in nitric acid (one to three parts water) free from hydrochloric acid; a few drops of hydrochloric acid were afterwards added to precipitate the silver, allowed to stand, then filtered, and the residue scorified with 500 grains of granulated lead and cupelled.

No. 1. Richmond River.—Placed on back of fifth pile in middle row from eastern end of twenty ton crane wharf, south training wall, Ballina, Richmond River. Fixed 1st November, 1893; in salt-water.

The assay of the new metal gave—

	Silver	*Gold.*
1000 grains gave	5 oz. 1 dwt. 6 grs.	11·8 grs. per ton.
1000 „	4 „ 19 „ 11 „	4 „

The trial sheet No. 1 after exposure at Ballina, as above, from November 11th, 1893 to September 30th, 1895. or about twenty-months gave the following results—

Scale—Consisted mainly of organic matter, 211 grains gave neither gold or silver.

Metal—Dissolved in sulphuric acid gave—

Silver—4 oz. 17 dwt. 19 grs. per ton. *Gold* contained platinum.

No. 1*a*. Moruya.—Placed on the pillar pile of the crane at the town wharf, say five miles from the heads. Fixed 11th November, 1893; in salt water.

No. 1*a*. Moruya. The plate was taken off in October, 1895, after being exposed to the sea-water for twenty-three months, and on assaying, it yielded the following results. Four assays were made, 1000 grains being taken; two of these were first treated with sulphuric acid and the other two with nitric acid, and the residues scorified and cupelled separately.

By sulphuric acid, mean of two assays—

Silver.	*Gold.*
5 oz. 0 dwt. 11·5 grs.	1 dwt. 1·8 grs. per ton.

By nitric acid, mean of two assays—

4 oz. 8 dwt. 5·5 grs.	1 „ 1 „

It is noticeable that the treatment with nitric acid gives a lower amount than that with sulphuric acid. The scale from this plate (110 grains) gave no gold, and under two ounces of silver per ton, but as the scale was largely organic matter, and copper oxychloride, much importance need not be attached to the percentage of silver, The inner scale from this (100 grains) treated with sulphuric acid gave—

Silver -9 oz. 4 dwt. 5·76 grs. per ton. *Gold* contained platinum.

No. 2. Clarence River.—Placed on No. 4 pile, Yamba wharf. Fixed 3rd November, 1893, in salt-water.

No. 2*a*. Shoalhaven River. -Placed on back of second pile, eastern end of public wharf, Nowra. Fixed 31st October, 1893, in brackish water. The new metal gave—

	Silver.	*Gold.*
1000 grains gave	11 oz. 6 dwt. 17 grs.	16 grs. per ton.
(Dup.)	11 „ 9 „ 8 „	16 „
(Trip.)	11 „ 4 „ 2 „	16 „

No. 3. Macleay River.—Placed on front tier of piles at back side of pile from front of Belmore River wharf, and on second pile on up stream of wharf. Fixed 20th November, 1893, in brackish water.

No. 3*a*. Newcastle.—Placed on No. 5 pile, from west end of Newcastle and Hunter River Steamship Company's upper wharf, Morpeth, at low water spring tides. Fixed 24th November, 1893, in salt water. The new metal gave—

	Silver.	*Gold.*
1000 grains gave	10 oz. 10 dwt. 6 grs.	10 grs. per ton.
(Dup.)	10 „ 9 „ 5 „	4 „
(Trip.)	10 „ 11 „ 8 „	8 „

No. 4. Richmond River.—Placed on sixth pile from eastern end of middle row of twenty ton crane wharf, south training wall Ballina. Fixed 1st November, 1893, in salt water.

No. 4*a*. Shoalhaven River.—Placed on back of second pile, eastern end of public wharf, Terrara. Fixed 31st October, 1893,

in salt water. The new metal gave—

Silver.	*Gold.*
1000 grains gave 6 oz. 3 dwt. 19 grs.	1 dwt. 7·3 grs. per ton.

No. 5. Clarence River.—Placed on No. 3 pile, second row, Iluka wharf. Fixed 3rd November, 1893, in salt water.

No. 5*a*. Newcastle.—Placed on third front pile from end of wharf at Pilot Station, Newcastle. Fixed 30th November, 1893, in salt water. The new metal gave—

Silver.	*Gold.*
1000 grains gave 12 oz. 18 dwt. 17 grs.	1 dwt. 4·1 grs. per ton.

No. 6. Macleay River.—Placed on fourth pile in second tier, front of Jerseyville wharf, and on front of pile, Fixed 25th November, 1893, in brackish water.

No. 6*a*. Shoalhaven River.—Placed on back of corner pile of Government wharf, Appletree. Fixed 30th October, 1893, in salt water. The new metal gave—

Silver.	*Gold.*
1000 grains gave 10 oz. 5 dwt. 3 grs.	1 dwt. 7·3 grs. per ton.

No. 7. Richmond River.—Placed on second pile northern end of middle row, low level wharf, Coraki. Fixed 4th November, 1893, in brackish water.

No. 7*a*. Newcastle.—Placed on No. 45 pile (front) near No. 11 Hydraulic Crane, Bullock Island. Fixed 30th November, 1893, in salt water. The new metal gave—

Silver.	*Gold.*
1000 grains gave 6 oz. 15 dwt. 10 grs.	1 dwt. 2·6 grs. per ton,

Plate No. 7 was taken off on September 25th, 1895, after having been exposed about twenty-three months, and examined with the following results—

Silver.	*Gold.*
By H_2SO_4 5 oz. 19 dwt. 3·8 grs.	Contained platinum.
By HNO_3 6 „ 0 „ 3·5 „	1 dwt. 15·2 gr. per ton.

The scale (30 grains) from the plate exposed at Coraki for twenty-three months gave 4 oz. 13 dwt. 15·5 grains silver per ton.

2 dwt. 4·2 grs. gold per ton., but the amount available, thirty grains only, was so small that the results are of but little value.

No. 8. Newcastle.—Placed on No. 11 pile from west end of Newcastle and Hunter River Steamship Company's wharf, Morpeth, at low water spring tides. Fixed 24th November, 1893, in salt water.

No. 8*a*. Moruya.—Placed on an iron bark pile (sleeper) western end of Pilot's Main boat-shed at the heads. Fixed 11th November 1893, in salt water. The new metal gave—

Silver.	*Gold.*
1000 grains gave 6 oz. 7 dwt. 14 grs.	1 dwt. 2·6 grs. per ton.

No. 9. Clarence River.—Placed on No. 3 pile, Bushgrove wharf. Fixed 3rd November, 1893, in salt water.

No. 9*a*. Moruya.—Placed on centre pile of third pier of Moruya bridge, counting from Mullenderree side. Fixed 11th November, 1893, in salt water. The new metal gave—

Silver.	*Gold.*
1000 grains gave 11 oz. 10 dwt. 2 grs.	1 dwt. 4·1 grs. per ton.

No. 10. Moruya.—Placed on the pile of Pilot's tide gauge at the heads. Fixed 11th November, 1893, in salt water.

No. 10*a*. Shoalhaven River.—Placed on the back of third pile from south end of wharf (front row of piles). Fixed 28th October, 1893, in salt water. The new metal gave—

Silver.	*Gold.*
1000 grains gave 5 oz. 18 dwt. 21 grs.	15·6 grs. per ton.

No. 11. Clarence River.—Placed on second row Lower South-gate wharf, No. 4 pile. Fixed 3rd November, 1893, in salt water.

No. 11*a*. Macleay River.—Placed on second tier of piles from face of Stuart's Point wharf, on second pile on up stream side, also nailed on up stream side of pile. Fixed 18th November, 1893, in brackish water. The new metal gave—

Silver.	*Gold.*
1000 grains gave 11 oz. 19 dwt. 18 grs.	1 dwt. 7·3 grs. per ton.

No. 12. Richmond River.—Placed on back of fourth pile, middle row from southern end of High Level wharf, Coraki. Fixed 4th November, 1893, in brackish water.

No. 12*a*. Macleay River.—Placed on middle pile of outside tier and on back of pile from front of Central Kempsey wharf. Fixed 21st November, 1893, in brackish water. The new metal gave—

	Silver.	*Gold.*
1000 grains gave	11 oz. 14 dwt. 5 grs.	23·5 grs. per ton.

Only three of the experimental plates have been removed and assayed, viz., No. 1 Ballina, No. 1*a* Moruya, and No. 7 Coraki, after an exposure of twenty-three months ; the others will be left on for a longer period. In all three cases there was a loss in silver and an increase in the amount of gold.

It is unfortunate that the presence of the platinum in the otherwise pure sulphuric acid was not detected earlier, as I have not the time now to repeat the determinations of gold which had to be rejected on that account ; but even without them there are perhaps sufficient assays to settle the question.

The average amounts of gold and silver obtained are :—

	Silver. oz. dwt. grs.	*Gold.* oz. dwt. grs.
12 specimens new muntz metal	9 4 7·6	0 0 23 per ton
10 „ old „	4 13 19	0 0 16·2 „
Average decrease	4 10 12·6	0 0 6·8 „

It is not quite satisfactory to have to compare the assays of old specimens of metal with those of new ones, but the old specimens of muntz metal are not likely to have originally contained less gold and silver than the new, in fact they probably contained very much more, so that the difference is all the more striking. The assays of the metals from the "Topsy," the second lot from the Circular Quay and from Newcastle are omitted from the above because some of them were made with the sulphuric acid afterwards found to contain platinum.

Next the scale from the ten old sheathings gave an average of

Silver.	*Gold.*
5 oz. 17 dwt. 8 gr. per ton.	8 dwt. 1·8 gr. per ton.

or an average increase in round numbers of over 7 dwt. of gold, and an average decrease of 4 oz. 6 dwts. 23 grs. of silver as compared with the new muntz metal.

The amount of gold yielded by the old metal and the scale is probably understated, since the chlorides could not be entirely removed from the old metal and they were very abundant in the scale, hence on dissolving in nitric acid some of the gold passed into solution as chloride and was lost.

The results do not altogether agree with the previously published views nor with my own before I commenced the investigation. The silver has not accumulated, but on the contrary decreased, the scale however, contains a larger amount of gold. The increase of gold in the scale may be due to the deposition of gold from the sea-water on to the surface of the metal, or it may be due to the comparative non-solubility of gold in sea-water; the muntz metal having been corroded and dissolved away, together with much of the silver leaving the gold behind: it is probably due to both causes, *i.e.*, partly to deposition and partly to accumulation, for the superficial parts of the experimental plates Nos. 1, 1*a* and 7, obtained by scraping them, show an increase in the amount of gold and a decrease in the amount of silver, the increase in the gold cannot in these cases, well be due to mere accumulation, since the plates do not appear to have lost sufficient weight to materially increase the proportion of the residual gold.

Under the microscope some of the old sheathings show minute specks of what looks like filmy gold, they may be particles of bright muntz metal, which have been deposited on the crust of oxychloride, oxide and other compounds forming the scale, for brass is deposited electrolytically; on treatment with nitric acid they disappeared in the effervescence set up by solution or other-

wise—these filmy specks are quite distinct from the points of bright muntz metal which are seen on the old sheathing, and penetrating, as it were, the scale or crust, and I am inclined to regard them as gold.

As I have pointed out elsewhere, under certain conditions gold is thrown down from very dilute solution by the action of reducing agents, in the form of bright particles or crystals—the amount of gold in such a particle might be extremely small, for $\frac{1}{5,000,000,000}$ grain of gold leaf is visible under the microscope, a piece of corresponding size set free from gold lace would of course be far less in weight. I hope to investigate this matter further, and in the course of another two years it may be desirable to complete this series of experiments by examining the twenty-one plates which have been left on the piles for a longer exposure.

SOME FOLK-SONGS AND MYTHS FROM SAMOA.

By JOHN FRASER, LL.D.

[*Read before the Royal Society of N. S. Wales, August 7, 1895.*]

ʻO LE TALA I LE SEGA.

"*The story about the Senga bird.*"

(THREE VERSIONS, NOS. XXXV., XXXVI., XXXVII.)

—o—

INTRODUCTION.—The three myths, which I now present to you, about the Senga parroquet, again show us how intimately Fiji and Samoa were connected in the minds of the early myth-makers. The incidents of the story are laid in the time of Taʻe-o-Tangaloa, the first king of the Samoan group, and the immediate successor of the gods who had previously ruled there. And yet in this myth, as in several others, there is a coming and going between Fiji and Samoa—a black race and a brown race—and there is a familiarity of intercourse which draws me to the opinion that the people of these two groups are related as to their history. In another

myth Tangaloa, the great creator-god of the Polynesians, is said to have had two sons, the one black in colour and the other reddish. So it may be that the brown inhabitants of the islands of the eastern Pacific are only the descendants of a fair race grafted on to a black race, the original occupants of these isles.

The Senga of the story is a parroquet, having a remarkably bright crimson plumage. It is still common in Fiji and Samoa; its feathers are used for personal and artistic decoration, but those from Fiji are the most valued. This particular Senga, however, is the first progenitor of the present breed, for it was born, not hatched, in the first heavens, and was the child of semi-divine parents. So says this 'tala.' Nor let us wonder at that; for such fables have a place in many old mythologies; the classical scholar will remember the parentage of the Cretan Minotaur, and even Livy's history has now and again chapters which tell of prodigies of a similar kind. And from the Samoan Story of Creation and other Samoan myths which I have read to you on former occasions, it is evident that the Polynesians thought of the heavens as peopled by men and women such as we are, all except the Ninth Heavens where Tangaloa, the Supreme, sits alone in his *Fale-ula*, his 'Palace of Brightness,' far removed from the turmoil and storms and passions of earth and the lower heavens. These heavens are occupied by the Sā-Tangaloa, the children of the creation of Tangaloa; they behave there like ordinary men, for they feast and chat together round the fire-light at night; they lie down to sleep, and the cocks crow to tell them that the day is coming; they marry and are given in marriage; up there they have the food of mortals, but of a more excellent kind—'taro' and yams and bread-fruit to eat, and 'kava' to drink; they hold *fonos* or councils and talk there to their heart's content; they have visitors from the earth below; for, if you go round by the north, says this myth, you can easily get up to the sky; these visitors sometimes cheat the Sā-Tangaloa, or rob them, or steal from them; sometimes they fight them and overcome them and carry off the spoils of victory, as is shown in the myth (No. 31) about Losi and Malae-La, 'the war of the gods and the giants.' The heavens also have natural features, such as those we see on earth; there is a *vaitua*, a pool in which, it seems, the Sā-Tangaloa may bathe; there is a *puna-langi*, 'a heavenly spring,' which issues from a cave; near this there is a raised heap of stone, something like an altar, on which offerings may be laid. In short, things go on there in Tangaloa's heavens very much in the same style as on the Polynesian islands below. All these views of heaven show themselves in this myth and in the others which I have published.

I have said that the Senga bird has bright crimson feathers; that colour associates itself with sun-worship; and besides its birth in the first heavens where the sun is, the tenor of the rest of this story proves that there was something divine in the bird; for, on one occasion, when buried along with its master, it still lived on in the grave, and sprang up again when it chose; it perched on a tree and nothing but the supernatural power *(mana)* of Le-Folasa, 'the prophet,' could induce it to come down. For these reasons I think that the Senga, to the Polynesian mind, was an emblem of the sun and connected with sun-worship. In the Vedic hymns, its colour is a sun-colour. The sixth hymn of the Rig-Veda (first book) has many passages to that effect; such as:—The red birds (of the Asvins) came back by day; The red birds shield you (the Asvins) around by day from the heat; The night retires from her sister the dawn, the dark one yields the path to the red; May the winged beautiful horses, may the red birds bring you (the Asvins) back near to us; Like the red child of heaven [*i.e.*, the sun]; The red [*i.e.*, the sun], with beautiful wings; The red horses, the beautiful, are seen bringing to us the dawn; Shine, O Agni, red among the dark ones; Powerful red horses, drawing together, draw him, Brihaspati [*i.e.*, fire, the sun], horses clothed in red colour like the sky; Agni, born red in the place of the altar; They yoke the bright red horse [*i.e.*, the sun]; Agni yoked the two red horses; and so on. Even the Fijian and Samoan languages tell the same tale; for the Samoans, when the sun *shines dimly* say, 'senga-vale'; in Fiji 'singa' is *daylight* and 'mata-ni-singa' is '*the sun*.'

Having thus disposed of the surroundings of this *tala*, I will now give you the gist of the narrative itself. Ua, the daughter of Tangaloa of the second heavens, was the mother of the Senga. She expected a son, but it was a bird—the Senga,—which at once took to the Heavenly Pool as its place of abode. There Ua and her husband faithfully fed their feathered child night and morning with 'taro' and breadfruit and fish. When full-grown, it loved to wander about. One day it went down to earth below and visited Fiji; there its brilliant plumage charmed Tui-Fiti, 'the king of Fiji,' and, like many a despot, he resolved to possess it. So he got two of his strong men to go up to the heavens to get hold of it by craft and bring it to him. Thus it was brought to Fiji and lived there. About this time Ta'e-o-Tangaloa, the first king of Samoa, who, like some of the Homeric heroes, was both Διοτρέφης καὶ Διογένης βασίλευς, came to visit his sister, the wife of Tui-Fiti. He too saw the bird and coveted it; but, as the nobility of his birth and rank made him disdain to steal, he asked it from Tui and got it. He took it back with him to Manu'a of Samoa.

A sneaking fellow of Tutuíla, a neighbouring island, next desired to have it; for the fame of the bird's beauty had spread far and wide. So he came to King Ta'e pretending disinterested friendship, and brought him a present; for, in Samoa if you give a present, etiquette requires that you get a present in return, especially from a king. But the stinginess of the visitor was such that he thought to gain his end by presenting a superannuated hen, now quite unable to hatch. Tangaloa saw through his craftiness and gave him like for like—some roots of *kava* so stale as to be unfit for growth, when planted. Finding that the *kava* roots did not grow, he came back to Tangaloa, and, on the confession of his fault, he got the Senga and took it away to Tutuila.

Upólu, another island of the group, now wished to have the wondrous bird, and a man whose name was End-of-the-Sugar-cane-leaf thought to get it, but he stole a canoe—'the Rainbow,' its name—to be the purchase money for it. The beauty of this 'Rainbow' canoe was too much for the possessor of the Senga; so he gave the bird for it. But ill-gotten gains do not carry a blessing with them; for the Upolu man had scarcely got home rejoicing in his success, when an *aitu*—'a spirit-god'—struck him dead because he had stolen the canoe. These old Samoans evidently had some sense of the equity of divine justice. He died and was buried, and they buried the Senga with him as part of his property. But the Senga's heavenly origin enabled it to live still in the grave, and soon it was up among the trees again and flying about from island to island. One day it visited the island of Savai'i and king Malietoa saw it; the usual effects followed; he must have it; so he sent for the whole priestly power of his island to charm the Senga to come down and be his bird; but they could not. Like the imperious Nebuchadnezzar in dealing with his magicians when they failed to interpret his dream, Malietoa ordered all these priests to be bound, ready to be slain and feasted on at the bidding of the man who could prove himself able to charm the Senga. Some one suggested that such a man could be found only in Manu'a. So an ambassador was sent to fetch Tangaloa who was the Tui-Manu'a; he readily came, and by his divine power soon brought the bird down and gave it to Malietoa. The Savai'ian magicians were spared, but they were converted into courtly barbers and family priests. And so ends this *tala*.

XXXV.—The 'Senga'—*A 'Tala.'*

1. The 'Senga' was the child of O and Ua. O was the son of Tangaloa-pu'u of the first heavens, and Ua was the daughter of Tangaloa-lua-lua of the second heavens. Ua conceived, and

brought forth; it was not a man-child but a bird, the 'Senga'; it sprang into the fresh water of the Heavenly Pool. Then they (two) gave it food; in the evening they fed it before sleep; in the morning they went early to feed it. They used to go with a tray, and cut up the 'taro' and bread-fruit and fish; they placed [the food] on the tray when they went to feed the 'Senga'; they laid it out on a raised heap of stones at the stream which sprang from a cave at the end of the pool.

2. The bird was [soon] full-grown; it sprang down; it went about [on earth] below. [One day,] it stood in the boat-opening of Fiji; Tui-Fiti saw it, and desired it. He summoned the Fijians to assemble; so Fiji held a council. 'Who is a strong man that will get this bird for me'? Olo and Faua offered themselves. Tui-Fiti showed them [what to do]: 'You two will go by way of the north side' [said he]. They went and found the road to the heavens; they arrived there; it was fire-light [time]. The family were talking [and said to them], 'Have you two come'? 'Yes.' 'What is your errand'? 'Is it true that there is a Senga sleeping there'? 'Yes, the child of Ua and O, which is fed night and morning.' 'What is it fed on'? 'It is fed on bread-fruit and taro and fish, placed on a tray.' Just then the Senga came gliding down behind the cave [to be fed].

3. The family took their fish [to it]; but they two went off and hid; and thus they saw [where] the tray of the family [was put]. The cocks crew [that is, morning was coming on], and they ran off with the tray. They placed it on the heap of stones at the pool, along with the things which they had prepared. The bird came gliding down [for its morning food], and they at once seized it. Then they ran away with the Senga. They took it to Tui-Fiti. It remained with Tui-Fiti. It was there at the time that Ta'e-o-Tangaloa visited his sister Moe-u'u-le-Apai. He saw the Senga and desired it. And when the Fijians had gone inland [to work], he told Moe-u'u-le-Apai that he desired it. Then Moe spoke to Tui-Fiti, and he gave it to Ta'e-o-Tangaloa. He came back to Manu'a and placed it in Fiti-uta.

4. Langafua came from Sita or Nu'u-uli in Tutuila. He wanted to become the bosom friend of Ta'e-o-Tangaloa. He came with a crowing-hen. Then Ta'e-o-Tangaloa [guessed his errand and] brought the 'kava.' He divided it and left the knot, but he threw to Langafua the 'va-i-ata' [rooty fibres?] to pay for the fowl which does not hatch. Langafua went to Sita with the 'va-i-ata.' He thrust them [into the ground] and they did not grow; the [roots] were rotten, for they were stale. Then he came again. Tangaloa asked, 'What is become of your kava? is it dead'? 'Yes.' 'I gave you the 'va-i-ata,' because you brought the hen that does not hatch; but, come now, take the Senga if you wish it.' Then he went off with the Senga; he took it to Sita or Fanga-fu'e.

5. Then tidings came to Upolu that Langafua had the Senga at Fanga-fu'e. Then they greatly coveted it. Then a purchaser came from Ua-fato [in Upolu]; it was the son of Le-Anga that came, whose name was Ngata-lau-tolo. He came with a canoe that was stolen; it was called Se-mata-e-'emo. Then Langafua coveted the canoe and he gave the Senga for it. Immediately thereafter the Upolu man died, [for] the 'aitu' was angry because the canoe was stolen. Then he was buried and the Senga was buried with him: but the Senga still lived. There is a *Solo* [*i.e.*, song] about that; [as follows]:—

The 'Solo.'

1. Langafua entered into friendship with him.
2. He desired a family alliance with Ta'e-o-Tangaloa.
3. He brought the bird that does not hatch;
4. He brought the crowing-hen;
6. He brought it and Tangaloa guessed his mind.
7. He gave him the 'vaiata,' but left the knot in Manu'a.
8. The 'Rainbow' canoe went out a-fishing.
9. [With it] Ngatā-lau-tolo bought [the 'Senga'] of his desire.
10. Then the 'Senga' went [with him] to Uă-fato.
11. "Malietoa, receive now your bird."
12. The son of Le-Anga was gone [*i.e.*, he died].

13. They buried the Senga with him; they two slept together;
14. The bird lay [there] with rottenness—
15. [But soon] it sprang up with a desire to eat.
16. [Thus] the Senga hatched through Malietoa's [care],
17. And overspread the whole group of islands.
18. "Malietoa, receive your bird."

O!

The Narrative continued.

6. The Senga lived on in the grave, and fed on the body of the man. But [soon] it went up into a 'pua' tree, among the hollow roots of the tree; it sprang into the 'pua.' It moved about from place to place; it wandered to Upolu; it wandered to Savai'i. Malietoa saw it and greatly desired it. Then he called a council; he collected the whole divine power of Savai'i [to ascertain] whether the Senga would come down; whatever [person having] divine power should be able to bring down the Senga, he shall have command and kill those who are not able. [They tried, but] the Senga did not come down, and all the priests were about to be put to death. Then Malietoa said that I'ite should come to this Manu'a to seek for a priest to bring down the Senga. So I'ite came to Tui-Manu'a. Then Tui-Manu'a said to Tangaloa-le-Folasa that they two should go with I'ite. They went, and were invited by Foisia, the god of Ofu, to call in. "Leave thy title and report to Pili-tafao."

7. They got to Upolu. Malietoa was set on high on a seat; a great multitude of people was gathered together; all the priests were prostrate on the ground; they were bound; they were about to be killed, because they were not able to bring down the Senga. They were covered over with native cloth. They were lying down for the blow at the direction of Pili-tafao.

8. Then Tangaloa-Tui-Manu'a stretched forth his hand: it perched upon his hand; then first he saw its head; the feathers on its head were short. He said to Malietoa, "That's your bird." Malietoa said, "Take the authority over these priests; if you decide that they are to be killed and eaten, it is well." Tangaloa

replied, "Don't; but let them live." Then Malietoa said, "Leave them to be my barbers and my priests."

XXXVI.—The 'Senga'—*A 'Solo.'*

1. Folasa came from Anga'e;
2. He was invited by Foisia to call in—
3. "Call in and signify your royal will
4. And report it to Pili-tafao,
5. Because I wish to be directed" [what to do].
6. The two guests [enter and] are pillowed on the threshold.
7. [Now by their power] the Senga that was borrowed is coming
8. The Senga that was so famed is coming. [down]—
9. The Senga wandered to the heights of Atua;
10. The Senga wandered to Tuamasanga;
11. The Senga comes down and perches on the cocoa-nut tree;
12. The Senga comes down and perches on the house's ridge pole;
13. The Senga comes down and perches on the house's upper beams;
14. The Senga comes down and perches on the middle beams;
15. The Senga comes down and perches on the lower beams;
16. The Senga comes down and perches on lowest tier of thatch;
17. The Senga is about to alight.
18. "O Malietoa, there is thy Senga [says Le-Folasa];
19. Let it suffice to turn aside thy wrath,
20. And let these sacred priests live,
21. And let the rain, the showers, and the sun still come on them."
22. He unloosed the priests that were bound;
23. The priests lived through Tangaloa
24. From the wrath of Malietoa.
25. "Change them [said he] into a band of barbers and house-priests
26. To shave off your offensive [hair] and cut your beard."
27. O Savai'i and Atua and A'ana and Tuamasanga,
28. You had Folasa afterwards; I was first, I was first. O!

XXXVII.—The 'Senga'—*A 'Solo.'*

1. Ua and O were princes of the Sā-Tui-Atua.

2. When you go to Atua seek for the land—an inland place,
3. And you will find it ; [then] speak about O and Ua.
4. As to the Senga, they gave birth to the child ;
5. They grasped it [in their arms]; it was not there ;
6. It had been changed into a Senga and sprang into the water,
7. And became the god of the water.
8. Moe-u'u-le-Apai [his wife] said,
9. "O Tui-Fiti, do you bring the Senga here,"
10. When [her brother] Ta'e-o-Tangaloa came to visit them.
11. It stood fast in the Le-tau-potu of Fiji,
12. And in the midst of their daily labour in fishing,
13. And at the fresh-water where they went [to bathe].
14. It bathed in the small boat-opening of Fiji.
15. When it was noon, it flapped its wings ;
16. The Senga did not come down ; it was cold.
17. Tangaloa the chief took it [away with him],
18. And let it go about over Savai'i.
19. "O I'ite, if you seek divine power, seek it in Taele-fanga."
20. Atua and A'ana with Tuamasanga came [and their priests],
21. [But] the Senga did not come down ; it was not familiar.
22. [Then] it wandered over Fale-ata [in Upolu].
23. "O I'ite, if you seek power divine, seek it in Manu'a ;
24. When you come back with the divine power of Tui-Manu'a,
25. Upolu will laugh at the beaching of your canoe.
26. To your right is the thing you are to look to ;
27. Its hair is short ; it has been clipped."
28. The red bird is jumping up and down ;
29. The divine power lies in the front part of the house.
30. Tui-Manu'a holds out his hand for the Senga.
31. It stands on the back of his hand ; he places it on a perch.
32. "Malietoa, [says he,] there is your Senga ;
33. I am going away, and shall not return ;
34. Allow the Senga to wander about [at liberty] ;
35. Hide it away when there is continual war.
36. Look up to To'elau, [for]

37. From Fale-'ula all honours come.
38. [If you do not,] you will put me in danger [of losing my honour],
39. For my honour will be scattered to and fro,
40. And, dispersed, will disappear;
41. For, from this achievement comes my title of Pe'a.
42. [So, I say,] unbind the wise men of the long hair,
43. But let the short-haired 'folasa' have the divine power."
44. Upolu, this is the [real] tale of thy ancestors,
45. [Although now] you are a troup of idle talkers.
46. So also is Tui-A'ana—
47. The Tui-fa'atu-Lalofata—
48. The child of the worm and the rotten 'fue.'
49. [I assure you] this Senga grew up in Manu'a;
50. The Senga came down through my divine power.
51. Bring him along and place him on his perch;
52. Put him to rest on his sleeping place.
53. [But] in vain do you contend with our Manu'a;
54. You will grasp at [the honour] in vain;
55. [For] the Senga did grow up at Fiti-uta.

O!

NOTES TO No. XXXV.

PAR. 1. *Senga* (pronounced saynga) is a small crimson parroquet, much valued for its bright-coloured feathers which are used for adornment. It seems to have come originally from Fiji, but is quite common both there and in Samoa. The feathers from Fiji are the most valued.

Child; fanau; *son*, atali'i, 'a commoner's son,' but alo is 'a chief's son'; *short*, pu'u; *second*, tua-lua.

A man-child; se tagata; *Heavenly Pool*, puna-lagi, 'the spring of heaven.'

Tray; laulau, which is a plaited cocoa-nut leaf.

Cut up; tofi-tofi, 'to split up,' 'to divide'; the food is cut up for the parrot's use; the islanders still feed birds thus on bread-fruit.

To feed the Senga; 'feed,' taumafa, a chief's word, in honour of the Senga. The Samoans often address their pet birds in chiefs' language; but 'taumafa' is used here, I think, from a feeling of reverence for the Senga.

Spread it, &c.; the whole clause here is—'fofola i le au tanu o le vai, oso mai mai le ana i le mulivai.' There seems to be something sacred

about this 'au tanu,' 'heap of stones'; it may have been an old altar. *Stream* and *pool* are both 'vai,' 'fresh-water.'

2. *He summoned the Fijians to assemble;* 'ua fonō ia potopoto Fiti.'

Strong man; fita-fita, 'courageous.' There is something divine about the Senga, and he who attempts to capture it runs a great risk.

Olo is a 'fortress.' *Faua* may be from *fau* 'to tie together, to build.'

By way of the north; 'i le itu i matu'; *itu* is 'side'; *cf.* 'the sides of the north.'

It was fire-light; mumu afi, 'the fires were burning.'

The family were talking; 'talatala le aiga'; that is, the Sa-Tangaloa were seated round the fire and were chatting.

Have you two come? 'po ua oulua o mai.' The common Samoan welcome is, 'You are come'; *cf.* our *welcome.*

What is your errand? 'se ā le feau'? *Night and morning;* 'po ma taeao.'

3. *The family took their fish,* &c.; 'ua ave e le aiga la la i'a, a ua la tuu ua nana; *their, they;* that refers to the *two* visitors.

The cocks crew; 'ua vivini moa,' for daylight was now approaching.

Desired it; 'manao'; 'gone inland,' that is, when they were gone off to the plantations to work. *Gone;* liu, 'turned.'

4. *A crowing hen;* 'ufa-ufa-ma-toa'; a crowing hen that does not breed, brought as a present in expectation to get something in exchange.

Left the knot; 'tuu le pona'; it is the knot that sprouts; *divided it;* 'vaea'; *raiata* are the root-branches that do not sprout. For information about the 'kava,' see Nos. IX. – XIV.

Were rotten; 'ua pala'; *stale,* 'mati,' from being too long kept.

I gave; avatu. *Angā,* 'action'; Ngatā-lau-tolo, 'end of a sugar-cane leaf.' Se-mata-e-'emo, 'a flashing eye.'

He died; a punishment for impiety.

THE SOLÓ—1. *Entered into friendship;* fa'auō. 2. *Family alliance;* aiga.

3. ***The bird that does not hatch;*** **'le manu e lē fofoa.'**

8. '*Rainbow*'; Aulima'o, the name of Langafua's canoe.

12. *Gone;* maliu, 'gone, dead;' *son,* 'alo,' a chief's word.

14. *Lay with rottenness;* 'e toaga i le palapala.'

15. *Eat;* taumafa, 'to eat *or* drink,' a chief's word. This incident shows the divine power of the bird.

PAR. 6. ***Among the hollow roots;*** **'i a'a ōō o le laau.'**

Moved about from place to place; eva-eva; *wandered;* eva.

Divine power; māna; the 'taula aitu,' that is, the magicians and priests are summoned.

Kill all that are not able; 'ma fasi i e ua lē mafai.' This is quite like the doings of despots; *cf.* the history of Daniel.

Put to death all the priests; 'a fafasi māna uma.'

I'ite means 'a seer, a prophet'; *ite,* 'to know.'

God; aitu, 'a spirit, an inferior god'; *to call in;* afe.

Leave thy title or *signify thy will;* the original here is,—'tuu lou ao sei logo ia Pili-tafao.' The meaning is not clear. Pili-tafao *or* Mo'otagao was the sister of Ta'e-o-Tangaloa and wife of Foisia, an *aitu* or god of Ofu.

7. *Sit on high on a seat;* 'ua ti'eti'e i le nofo.'

All the priests were prostrate; 'taatitia māna uma,' waiting their doom.

Native cloth; u'a; made from the bark of the paper mulberry.

8. *And eaten;* 'e fai taumafa,' a cannibal feast; *don't;* 'auă.'

Notes to No. XXXVI.

Line 1. *Royal will;* observe that a king was in a sense sacred; for, where he sat, nobody else could sit; no one could touch his food. On each side of a king sat a 'tuafale,' the head man of a family. Chiefs were termed *pa'ia*, 'not touched by work, sacred.' *Folasa*, 'a prophet.' *Angae* is a district in Manu'a.

2. *Invited;* velaau-ina; as when persons are passing by and are invited to come in and partake of food.

3–5. The text of these two lines is:—

v. 3. Afe mai sei tuu lou ao; *v.* 4. Sei logo ia Pilitafao; *v.* 5. Aua ni tonu mo au; *or* T'autua na ni tonu mo au.

6. *Guests;* 'tatāluma,' which is the front part of the house, and honoured guests are set there; *pillowed*, 'aluga,' used as a verb. There must be some peculiar reason here for their laying their heads on the threshold to sleep. The 'lagolaai' *or* threshold is a few inches above the ground and may thus be used like the wooden pillow of the natives; *lago* means 'to raise on supports,' and *laai* is 'to pass over.' With this threshold-sleep, compare the superstitions in many countries about stepping on and over the threshold; compare also I. Sam. v., 4.

7. *Borrowed;* nono; referring to its first coming from Fiji.

8. *Reported;* logo; that is, 'much heard of, famous.'

9. *Wandered;* the word thus translated here and elsewhere is the causative 'faa-eva.'

11–16. These lines represent the gradual descent of the bird under the magic influence of the 'folasa.'

Perch; 'tu,' stand; *ridge-pole*, 'au-au'; *beams*, 'tausoaga'; *upper*, 'luga'; *middle*, 'loto'; *lower*, 'lalo'; *lowest tier of thatch*, 'lagolau.'

17. *Alight;* ē tapā; the translation of this word is conjectural.

19, 20, 21, 25. The text of these lines is:—

v. 19. E tau ane ai lou toasā; *v.* 20. A e soifua mana sā; *v.* 21. Fa'aua ma fa'atimu ma fa'atā; *v.* 25. Inā 'ē liu falesoga ma liu falemana.

26. *Offensive;* soesā; the text has no word for hair.

28. *I was first;* Manua says this.

Notes to No. XXXVII.

Line 1. *Princes;* tui; Sā-Tui-Atua is 'the race of the princes of Atua.'

2. *Land;* laumea—the land which is the birth-place of the Senga.

Water; vai, 'fresh water'; '*god,*' atua; '*changed,*' liu.

8. *Moe,* &c.; she hears of the Senga from her brother; she hears of the beauty of the Senga of Atua in Samoa and covets it; but when brought to Fiji, it "stood fast," it would not come down to them (*v.* 11).

12. *Daily labour,* &c.; faiva o tili; *tili* is the casting of the small net.

13. *Fresh water;* they bathe in a swamp or lagoon of fresh water.

14. *Small boat-opening;* ava-ava.

15. *Noon;* ao-uli; the original of this line is:—'O ao-uli a sua tāili; which may also mean, 'At noon (*or* at full tide) a wind springs up.'

19. *Bathing place;* taele faga.

20. *Atua,* &c.; that is, all the priests of these districts in Upolu came.

21. *Familiar;* lata; it did not feel at home.

23. *Power divine;* māna; power to charm the bird, which the priests of Upolu had been unable to do.

25. *Laugh;* ataina; as scoffers and unbelievers when you land there.

26. *To your right,* &c.; this line may also be translated, 'Consider the distinguishing mark it has,' [for]

28. *Jumping;* this is the effect of the Folasa's *māna.*

29. *Front part;* talāluma.

35. *Continual war;* utu tau; the Senga seems to be a bird of peace, probably as an emblem of the Sun, the beneficent orb of day.

37. *All honours;* ao; the line is '*Faleula* e tutupu ai ao.' *Fale-ula* is the bright palace of Tangaloa in the highest heavens; and To'elau is a group to the N.W. of Samoa, but it seems to mean something else here.

39. *Scattered;* e fa'a-eva-eva, 'made to wander about.'

40. *Dispersed;* that is, scattered to the winds; *disappear;* maulu, 'dive under.'

41. *Pe'a,* 'a bat,'—a title of nobility in Samoa; the line is, *Tupu ai na tonu mai Pe'a.* 42. *Wise men;* folasa.

44. *Opolu,* &c.; the Manuan poet concludes, as usual, with some lines to magnify the importance of his own islands of Manu'a.

48. *Rotten fue;* fu'epala; for explanation of this, read the Samoan Story of Creation, No. xxx. 51. *Perch;* sunuaga.

XXXVIII.—The Story of Moi-u'u-le-Apai and her husband Tui-Fiti, the king of Fiji—*A 'Tala.'*

—o—

Introduction.—The *tala* that now follows has in it two of the characters who appeared in the previous one,—the semi-divine Ta'e-o-Tangaloa, and

his sister, Moi-u'u-le-Apai; and the time of the story is again the grey dawn of Samoan history, when Ta'e was the first king. Ta'e was a bigamist; he had two wives at once, and they seem to have made the family home so uncomfortable to poor Moi that she fled from it, and, committing herself to the deep, she at last reached Fiji; here her charms as a brunette captivated Tui-Fiti and he married her. To this hour the Fijian princes like to marry brown Polynesian women, and, the Tongan group being nearest to them, they get wives from it. But in these myths Tonga is of no account; it is Samoa only that has intimate relations with Fiji,—a black race with a brown one. But this foreign lady was not acceptable to the subjects of Tui-Fiti; for, had her presence not brought on that land this sore dearth of food from which they now suffered so much! And so, in heathen lands, it is the stranger among them who is accused of bringing the destructive epidemic, and he must be driven away that it may be stayed. Some philologists say that the Latin word *hostis*, 'enemy,' originally meant only 'a stranger,'—truly a striking glimpse of the philanthropy of the time when every stranger was reckoned an enemy. So poor Moi was again a wanderer; for the king of Fiji had to send her away to satisfy the clamours of his people. And yet, when she was gone, the famine still remained. We see her tramping on inland towards the high mountain ranges of the island, carrying her own little boy on her back, and leading by the hand Tui's sister's son, an adopted child. At last they reached a spot where they thought to rest; they sat down and wished for a house, when, lo! at the wish, a band of artificers, 'tufunga,' came down and built a house for them, sent for that purpose by the great god Tangaloa, her ancestor, who hears all the wishes of his own people. But he did yet more for her. Dwelling in that forest, how was she to get food? The family of Tangaloa in the heavens consulted together, and Ufi, 'a yam,' offered to go down and plant herself around the house, and bear fruit. Next morning, the exiled queen saw the yam, dug up a branch, took it into the house, roasted it and ate thereof, she and her two children; thus they did for many days—all through the beneficence of the great god.

Meanwhile her brother Ta'e-o-Tangaloa in Manu'a had dreamed a dream, also sent by the supreme god of the Polynesians—does not Homer also say that dreams come from Zeus? *καὶ γὰρ τ' ὄναρ ἐκ Διός ἐστιν*—and by it he knew that his sister in that far off land of Fiji was in distress. He must at once go to her help. A canoe belonging to a neighbour of his, Tui-Afono, was about to start for Tutuila, with four oarsmen and Afono himself the fifth on board as steersman. Knowing what he meant to do, (for was he not semi-divine?) he took in his hand a stripped cocoa-nut

stem and a bread-fruit branch, and, reaching the spot just as they were getting off, he hailed the canoe and said, 'I want to go with you!' Afono churlishly refused and pulled out of the harbour. Tangaloa hurried by land to two points which they had to pass in succession, and from each of them repeated his request, but thrice in all he had the same refusal. The canoe now got out to sea; but Tangaloa, irritated by Afono's repulses, called to his sea-boys (mermen, I suppose) and ordered them to bring the vessel by force back to the rock where he stood; thrice this was done, but to no avail; for Afono still refused; until his men expostulated with him on the danger they ran; then he yielded so far as to let one of them say to Tangaloa, 'Come here.' So Tangaloa jumped on board.

But it did not suit him to let the canoe go on to Tutuila, for he wanted to get to Fiji; so he enveloped that island in thick darkness and made the light to shine clear upon Fiji in the far distance to the south-west. The crew passed Tutuila as if it were not there and continued heading onwards for many days. Food and water began to fail them. Hungry and thirsty, Afono and his men cried to their miracle-working passenger. He bade them look into the hold; there they found bread-fruit to eat, and young cocoa-nuts from which they got water to drink. The branches which Tangaloa carried in his hand when he leaped on board had been placed in the hold, and they had speedily grown there, and now they supplied food and drink to the weary crew!

At last the canoe reached the Fijian shore, but here fresh dangers were before them. It was a charmed land, and three obstacles had to be overcome by those who would enter there; first, outside on the reef was a snare called 'the coral-that-wrecks-canoes,' probably something like the Symplegades rocks which of old so bothered the Argonauts when they essayed to sail between them; then inside there was a second danger in the shape of shoals of mullet which, by some magic influence, were made to leap on board with the intention of swamping the canoe: then, as a last and inmost bulwark stood on a promontory Tui-Fiti himself, with his pointing finger, to lead astray and to destruction those who would steer by his directions. From all these dangers Tangaloa, by his skill and foreknowledge, delivered Afono and the crew. At the last point, he laid his *mana* or divine power on Tui-Fiti for punishment; for he had only to point his finger upwards and the Fijian king fell prostrate and stunned, and the whole land of Fiji was scorched with heat. From this incident it appears that he who possesses the *mana* is superior to magic and plots, and thus the wickedness of the wicked only recoils with double force upon their own heads.

As Ta'e had now no further need of the canoe, he dismissed the Tutuilans with the assurance that he would enable them to get back to their own land in a few hours; but, if they wished to have prosperity and happiness, they were not to clear out the hold of their vessel till they were ashore; for the scales of the fish, and the skin and refuse of the 'taro,' bread-fruit and cocoa-nuts that they had eaten would be of much value to them. Perversity and unbelief seem to be congenial to the mind of men everywhere, for, although the crew said 'Aye, aye, sir,' to his injunctions, the men were scarcely out of his sight than they threw the whole lot overboard. And Tui-Afono thus missed having the plenty and comfort which the fruitful growth of these things would have given him.

Meanwhile, Ta'e was moving about on Fiji in search of his sister; at last he found her; they fell on each other's necks and wept. Next morning he commenced to plant her land with everything good to eat, and while there was miraculous abundance there, Tui-Fiti and his people on the coast were still pinched with the famine and dying of hunger. In these circumstances, Moi resolved to return to her husband good for the evil she had received at his hands, and, taking a present of food with her, she went down to the coast, got the sick man to eat, and, as he was too weak to travel inland, she had him carried up next day to her home; all his people soon followed and settled inland there, and thus escaped the famine. Then Tangaloa returned to his own Manu'a, and, in memory of his journey in search of his sister, he gave to a district in it the name of Fiti-uta, 'inland Fiji,' and that name remains till this day.

The 'Tala.'

An account of the praises of the boy of Moi-ulu-le-Apai, the relation by the mother's side of Ta'e-o-Tangaloa; an account of his going to Fiji.

---

1. Probably Moi-u'u-le-Apai went away [from home] at the time when her brother, Ta'e-o-Tangaloa, married Le-lau-lau-a-le-Folasa and Sina. She travelled on and reached Fiji, and married the chief of Fiji, who was called Tui-Fiti.

2. And so Moi, the daughter of Tangaloa-a-Ui, became the wife of Tui-Fiti; and she brought forth a son and he was called Le-Ata'ata-a-Fiti. There was a famine in Fiji at that time, and it was very great. Then the people said to Tui-Fiti, 'What do you think? should we drive away the lady? for she is not a human being but a god; because, since she came, we have constant famine; our food is gone.' Then she was sent away by the chief.

3. Then the lady caught hold of her boy, and carried him on her back; she went away also with her child whom they two had adopted; it was the child of the sister of Tui-Fiti; Fili was the name of that boy; these are the three that went. They walked far inland to the backbone of the island, to the place called Tau-potu of Fiji; they dwelt there; they got a house because they expressed a desire for it; thus they spoke as they walked :—

'O a'u, 'o a'u lava 'o Moi-ulu-le-Apai;
Matou o atu lavaia, o tumai se fale;
Matou te nonofo ai, ma si a'u fanau.

"I am, I am indeed Moi-ulu-le-Apai;
We came and a house appeared;
We dwelt there, I and my child.

4. Then Tangaloa looked down from above. He appointed a great many to hasten down to build a house for the lady. Then the sons of the Sā-Tangaloa went down; they built the house; the lady with her sons went there and the building of the house was finished, and the Sā-Tangaloa went back to the heavens; then the lady dwelt there and her sons. When morning light was come, a council was held in the heavens of those who built the house, together with all the Sā-Tangaloa, about food for the lady. Then Tangaloa said, 'Present an offering of food to her quickly, because the lady is hungry.' Then Yam offered herself saying, 'I here (I this) am Ufi-tolo-tie.'

5. Then the Sā-Tangaloa said, 'How will you go'? She said [the yam], 'I will go and grow at the side of the house, spreading there; when the lady goes out to look for food, then will her foot be pierced by me; then shall I be observed; she will look down and perceive that I am good; she will then take me to eat.' The Sā-Tangaloa were agreeable. Then the yam went down to the side of the house and spread itself along. When it was morning light, the lady said to Fili, 'Come here and stay with your young brother,' while I go and search for something to eat for us three: it is doubtful if I shall get any in this great forest.' When she came behind the house, the yam was spreading there, and her foot was at once pricked by the yam. The lady looked down;

the branch of the yam was broken ; it was scattered about ; she took hold of it ; broke it with her teeth and tasted it to see whether it was sweet ; she perceived that it was good ; then she dug it up. Then she went into the house, bearing the branch of the yam in her hands. Thus she brought it and roasted it for herself and her children. And they ate of it. Thus she did every day ; that yam became food for the lady and her children for many days.

6. Then it became known to Ta'e-o-Tangaloa by a dream : for he dreamt that his sister had been ill-used by her husband, the king of Fiji. Then he prepared to go there : but there was, towards the east, a travelling party from Tutuila ; the travelling party of the king of Afono had come to his friend, 'O Le-puia-i-lama. Then came Ta'e-o-Tangaloa at the time when the travelling party was about to return to Tutuila ; he seized hold of two things of his, a cocoa-nut stem from which the nuts have been picked and a bread-fruit branch with leaves and blossoms on it. The travelling party of Tui-Afono went on board, and Ta'e-o-Tangaloa said, 'I will make a sixth in your canoe.' Tui-Afono was unwilling [that is, refused]. Then his canoe passed through the boat-opening, and the chief (*i.e.*, Ta'e) went inland. The canoe passed through behind the breakers, but the chief went by land ; the chief came and stood by Le-Loto ; that is a rock on the seaside of the Pu'e-mapusanga. The canoe came there, and the chief said to Tui-Afono, 'Let me be a sixth to your crew.' He was unwilling ; Tui-Afono would not answer. The canoe went on, but the chief went by land. He came and stood on a reef-rock ; its name was the 'to'a' of Tangaloa ; it is on the sea-side of Ana-lefu in Fale-asao. The canoe went on and reached it. Tangaloa said to Tui-Afono, 'Let me be a sixth in your canoe.' The canoe went on ; for Tui-Afono was unwilling. It went on, and was far out at sea.

7. The heart of Tangaloa was pained. Then he called to his people who were there in the sea, Au-salia and Au-fanua-mai, 'You boys there give heed to me (*lit.*, turn your eyes towards me);

I am tired of this fellow, who has been fooling me; come now, do you two bring him to me; bring him to the place where I stand.' Then his men went; they brought the canoe; notwithstanding the sail and the paddling with oars, they brought the canoe to the place where the chief stood. Then he called again, 'Tui-Afono, let me be a sixth in your canoe.' He was unwilling; and the canoe went on; the chief let it go on. They went on and reached the spot where they had been [a little before]; it was brought back again; it was brought to the place where the chief stood. He called again, 'O Tui-Afono, let me be a sixth in your crew.' Tui-Afono did not speak. Then one of the crew—Gai-uli-ma-gai-sina it was—said, to Tui-Afono, 'Let us say the word that the chief may come' [on board]. He was unwilling and said, 'Pull away.' They reached the spot where they had been before; then the canoe was brought back to the place where Tangaloa stood. Then he cried, 'Tui-Afono, let me be a sixth in your crew.' Tui-Afono was unwilling. Then stood up his steersman and said, 'Tui-Afono, the chief, do you say the word to that chief; for, in consequence of your acting thus and your provoking ways, the end of it will be that we shall all be made to suffer for it.' Tui-Afono was unwilling, but answered, 'One of you, call out.' So one called, 'Come here.' Then the chief came and jumped into the canoe.

8. Then Tangaloa performed a miracle; he covered the sky and all the lands with darkness; only Fiji remained bright sky; there was light there; and the prow of the canoe was directed toward it; the crew and Tui-Afono were frightened; they thought they were turned towards Tutuila. Then they voyaged on: they continued to voyage on: the food was all consumed and the drink, and the days of the canoe were ended. The crew grumbled: Tangaloa asked, 'What is it'? Tui-Afono answered, 'Tangaloa, this crew is going to die; there is no food; the food is all consumed.' Tangaloa answered, 'Look into the hold of the canoe, towards the starboard side.' Then they looked carefully: the bread-fruit branch had fruited and become a live bread-fruit, and

now bore fruit. They brought it out and ate; for there was a cooking place in the canoe. Then the crew murmured for water. Tui-Afono again called out, 'There is plenty of food; but this crew is dying of thirst and there is no water.' Then Tangaloa bade them examine the port side of the hold. And when they examined, the cocoa-nut stem had fruited; it bore fruit well, both the young cocoa-nut and the full-grown nut.

9. The canoe continued its course and reached Fiji; it reached the back of the surf in Fiji. Then Tangaloa told them of the might of Tui-Fiti. Tangaloa gave them his final instructions. But he first said to the crew, 'In this land are the spirit-gods called the 'Wrecking Coral,' and the 'Leaping Mullet,' and the 'Fiti's Finger;' that is the pointing-hand that makes canoes to err and be broken, and the men die, but they do not altogether die; they only lie stretched out: this implies the divine power of Tui-Fiti, that a canoe should come safely to land.' Then Tangaloa made a last command, 'When we reach the boat-opening and I say, "Pull lustily," see that you obey me at once; for there, in the boat-opening, is the mullet that leaps, the '*anae-oso*'; when you see that you have enough of [them for] food, do you bid me cover up the hold, because of the pointing of Tui-Fiti; when you see me paddling on the right side, do you paddle also on the right-hand side; when you see me paddling on the port side, do you also paddle on the same side; do you paddle as I do: thus will ye paddle.'

10. So then the canoe entered the opening in the Fiji [reef]. Tangaloa stood on the half-deck and called, 'Paddle the canoe.' They pulled stoutly: the coral reef [that is the dreaded Panga-solo-va'a] was at once pierced and broken through, and the canoe went through the middle of the opening. Then the 'anae-oso' fishes jumped up and the canoe was nearly swamped. The crew shouted, 'Tangaloa, cover the hold.' Then the mullet jumped up [on deck] and wriggled about, and fell back into the sea. They went on, but there they saw the pointing [finger] of Tui-Fiti. Then Tangaloa paddled on the port side and all the crew paddled

likewise. Then came the pointing of Tangaloa : and Tui-Fiti fell prostrate and was stunned. Then the Fijians directed their attention to their chief and gave no heed to the boat : they did not stand and look towards it.

11. Tangaloa at once jumped ashore and placed the canoe on the supports there; the Fijian supports were at once broken: and now [the crew] turned the canoe seaward and went away. Hence is the song about the voyage of Tangaloa, thus :—

"The fleet of Afono prepared to go a-fishing.
Tangaloa stood up with the food for the journey.
The 'tusi' of Fiti pointed down ;
Tangaloa paddled on the larboard ;
[The canoe] swerved with its crew and went too far ;
The 'tusi' of Tangaloa pointed up ;
All Fiti was swamped by that."

12. Then he said, 'Now, you Tutuilans here, you will reach land in this very hour ; you will not sleep [another night] on the deep: don't bale out your canoe; don't remove the refuse from it; you Tutuilans here, drag up the canoe at once and its cargo; bale out the canoe for the first time when you reach the land.' They answered, 'Aye, aye: let it be so.' He said also to them, 'There is great happiness in store for you, if ye do these things ; for that [refuse] will produce fruit greatly—bread-fruit and cocoa-nut—and fish will grow also from the scales.' But they did not obey, for they baled out the canoe and threw out the refuse at the back of the breakers. Thus their happiness was wasted. Hence the proverbial saying, 'They have despised the good fortune of Tui-Afono.'

13. Then they speedily arrived at Tutuila. They were near the land ; the surf was behind them; they rejoiced that they had come so quickly. But they had baled out the hold and collected the refuse and thrown it into the sea, before they beached the boat. Then they reported to the people of Afono all the tale of the journey, and the great usefulness of the food of Tangaloa, and the final injunctions of Tangaloa ; and how they were grieved because

they had baled the canoe, and gathered up the refuse [to throw it away]; because if they had brought these things with them, that is, the scales of the fish and the skins of the 'taro' and of the bread-fruit, and the stems of the cocoa-nut, they all would have had great plenty. Therefore the people said, 'Tui Afono, you have made light of your good-fortune'; hence sprang the proverb, 'The good-fortune of Tui Afono was made light of.'

14. But Tangaloa went on for the place where his sister was; it was far off, far off inland. He reached [a house] about fire-light time, and went on early in the morning. When he got to the place, they were having a dance to the praises of Moi-uru le-Apai and her son Le-ata-ata-o-Fiti; thus:—

1. "The fleet of Afono prepared to go a-fishing.
2. Tangaloa stood up with food for the journey.
3. The fleet of Afono prepared to go a-fishing;
4. There was a search for Moi-u'u-le-Apai;
5. The whole lands were covered over [with darkness].
6. The Sā-Tangaloa voyaged;
7. They voyaged and he stood up at the boat opening:
8. [There were] the mullet and the coral-that-wreck canoes.
9. First the pointing of Tui-Fiti went down [*i.e.*, south];
10. Tangaloa paddled to larboard and so did the crew.
11. [Then] the pointing of Tangaloa was upwards [*i.e.*, north];
12. The whole of Fiti was scorched;
13. The Samoan group was covered [*i.e.*, protected]."

They [brother and sister,] greeted each other and wept: he stayed there, for it was night.

15. When the morning light dawned, Tangaloa said to Moi-u'u-le-Apai, 'Shut down the flaps of your house; let me prepare and plant your ground.' Then he planted the land everywhere. Bread-fruit lived there, and cocoa-nut and papaw-apple, and banana, and taro, and yams; everything grew abundantly. He kept on planting, and very great indeed was the quantity of food. They were free to use everything on the land; only the bread-

fruit crop was forbidden until the first fruits of it were taken to Tui-Fiti, who was oppressive to his lady. And Tangaloa's injunctions were obeyed.

16. In course of time, the crop became ripe, and the boy was grown up. But the famine continued in the towns in Fiji; one man was almost eating another; and Tui-Fiti was nearly dead with hunger. Then said Ta'e-o-Tangaloa, 'Gather some bread-fruit at sleeping-time, and early in the morning go and take it to Tui-Fiti.' Then they went and gathered the bread-fruit; four of these were a burden for the one boy and the lady. And with it they went down towards the sea to Tui-Fiti; they made their oven; there were three of them; they made their oven; the fruit was cooked and they took it down to the chief who was oppressive to her; the chief and his family partook of it and were strengthened.

17. Then the lady told Tui-Fiti that she was going back [home] with her child; and that if there were any who were still strong in his land, that they should come with her and carry the abundance of food that was inland—taro, bread-fruit, bananas. The chief replied, 'What does my lady think about carrying the sick man inland to be taken care of there.' The lady said, 'Please yourself: only your people will not be able to carry you, the sick man, inland until to-morrow; when to-morrow comes, you, the sick man, shall be taken; but to-day, if there are any that are strong, let us go ahead to bring down food to satisfy the hunger of the people.' Then a great number crowded up and went inland—men, women, and boys. They reached the plantations and saw white bananas; they ate, but did not gather burdens to take to the town; they ate; they were gorged; they were sick; then they slept inland and did not go down to the town. When the morning arrived, the sick man Tui-Fiti was brought up; then they remained inland; gradually all the houses of the Fijians were brought up; they took up all the town to the place where Moi-u'u-le-Apai lived,—to the abundance which grew in the plantations of Ta'e-o-Tangaloa.

18. They all went inland, and Ta'e-o-Tangaloa was there still. Then Ta'e-o-Tangaloa said to Tui-Fiti and Moi-u'u-le-Apai, 'Come now, set your country in order, but I will go away; I have got a name for my country; it is Liu-Fiti-i-uta "Changed-into-Fiji-inland"; that was shortened into Fiti-uta. Then he came here with that name for his land, Liu-Fiti-uta; he came and dwelt in it. I suppose that was at the time when Ta'e-o-Tangaloa was a young man.

Notes to No. XXXVII.

Par. 1. *Moi-ulu-le-Apai*; sometimes the *l* is dropped and the name becomes Moi-u'u; the *praises* of her boy is 'faa-nana-aga,' a 'song of praise.'

At that time; 'po,' night.

2. *Le-ata-ata-a-Fiti;* 'the after-glow of Fiji.'

Human being, tagata; *god*, aitu. 3. *Backbone;* a ridge of hills.

4. *He appointed a great many*, &c.; "tofia lea ni e toa-tele e nati-nati ifo e toai se fale." The word 'nati-nati' means 'to be busy about;' 'to be urgent, to be importunate.'

Present an offering of food; 'fe-ofoai mai ia ni 'ai'; 'ofo' means 'to make an offer of food and services to visitors.'

Ufi-tolo-ti'e; 'the yam which spreads along on the surface of the ground.'

5. *Morning light;* malama. *Scattered about;* pae-pae, *lit.*, 'piled up.'

It was sweet; some are bitter. *Every day; many days;* aso-uma.

6. *Afono* is in Tutuila; *his friend;* uō, 'a bosom companion'; Le-puia-i-lama, 'Shut-up-torch.'

Cocoa-nut stem from which the nuts have been picked is au-loso-loso; only fit for firewood when the nuts are gone.

Bread-fruit branch with the leaves and blossoms on is tau-'ulu-'ulu.

Le Loto; 'the pool'; *Pu'e-mapu-saga*, 'the pu'e (a spreading tree) resting place.' *Reef-rock;* to'a; *Ana-lefu*, 'cave-bad.'

7. *Au-salia or Au-agae*, 'cross-current to the east'; *Au-fanua-mai*, 'cross-current towards the land.'

Your eyes; pulā, an abusive term for 'eyes'; pula, 'to shine,' like ripe fruit. *Fooling;* playing tricks. *Chief;* ali'i; the gods also are chiefs.

Gai-uli-ma-sina, 'Gai- black-and-white'; *gai*, as a verb, means 'to be injured internally'; *gaigai*, 'to be exhausted' as by work in the sun.

Let us say; *lit.*, 'let your speech go forth.' *Pull away;* that is, 'paddle.'

Provokingness; fa'a-masei-sei; *masei*, 'to be uncovered as the body'; 'to use words giving offence,' although not so intended; *masei (adj.)* 'ungrateful, improper conduct.'

8. *Hold; lit.*, 'bottom.'

Young cocoa-nut is full of liquid; the *full grown nut* is full of food.

9. *Might; lit.*, 'troops'; *parting command*, 'tofiga,' like the injunctions which a dying father gives to his sons.

God; aitu, 'spirit-god'; *Punga-solo-ra'a*, 'the coral (that makes) canoes slip'; *Anae-oso*, 'the mullet that leaps'; *Tusi-a-Fiti*, 'the pointing of Fiji'; this *pointing* is done to direct the steersman and the rowers in passing through the reef, or coming inshore.

12. *The refuse or rubbish*; this is explained further on, PAR. 13.

14. *Fire-light time*; about 7 *p.m.*; *praises*, 'fa'a-nana-aga,' as in the title of this '*tala*.'

15. *Flaps*; these are moveable flaps, next the ground as in our canvas tents, which are raised in the morning for ventilation to the house.

Prepare and plant; chiefs work in their own plantations.

Papau apple; *Eugenia malaccensis*. *Forbidden*; tabu.

Sick man; lit., 'your sickness.'

17. *White* bananas; that is, thoroughly ripe.

Be able; 'sava' (a Tutuila word) for 'lava.'

Set your country in order; that is, appoint magistrates, &c., for orderly government.

XXXIX.—VALUA AND TIAPA—*A 'Solo.'*

—o—

INTRODUCTION.—Some persons may perhaps say that there is no evidence to show that these myths are not recent creations of the Samoan mind. To that I reply that the general cast of the stories proves them to be brethren of the ancient folk-lore tales of other nations, although modified by the tale-teller to suit his Polynesian environment. A wine-taster at once knows the quality of the wine offered to him and perhaps also the district from which it comes; so likewise can a folk-lorist discern from its very setting that a tale is genuine. Sometimes also there is internal evidence to the same effect; the language is old-fashioned and hard to understand; there are frequent allusions to old occurrences in the history of the nation, well-known to them, but scarcely intelligible to us; national proverbs are quoted, and such sayings are usually of very ancient date; and conceptions of the gods and their doings present themselves, which are quite foreign to the current modern ideas of the race.

Occasionally, however, we have a Folk-song like this, which looks like a charter of nobility taken from the muniment chest of some noble family. Such a *solo* tells of the rival claims to precedence made by some islands of the group, and the song is of such antiquity and well-known authority

that a mere quotation from it is enough. Of this nature is the following song about Vāl ia and Tiapa, founders of the tribes of Savai'i. Some of the people of that island deny the statement that Valua and Tiapa came from Manu'a, but to settle the dispute you have only to say '*Ia, fai mai se soifua*,' 'Come, tell us the story of a life,' for this story is called a *soifua* and decides the question. Some of the references in it are so old that the present generation does not understand them.

The Solo.

1. O Manu'a se nu'u au mamala.
   Manu'a is a land bringing calamity [if slighted].
2. Folau aitu, folau tagata
   [From it] spirits go a-voyaging, men go a-voyaging
3. I Saua ma Sopo-Le-Malama—
   To Saua and Sopo-Le-Malama
4. I le atu Toga, ma le atu Fiti—
   To the Tongan group, and to the group of Fiji;
5. Folau i le atu To'elau,
   They voyage to the Tokelau group
6. Ma Sa-Vavau.
   And to Sa-Vavau.
7. Fesili Nonoā le ava;
   Nonoa asks for the boat-opening;
8. Ai la outou folauga na.
   That, I think, is the place you have to go to.
9. A outou ō i A'ana;
   You are about to go to A'ana;
10. Tou afe a'e i Aleipata;
    You will call in at Aleipata;
11. I tua le Moso ma Le-Laulala,
    Behind it are Moso and Le-Laulala,
12. Ia mata'utia i Utu-fala-fala.
    Who are dreaded in Utu-fala-fala.
13. So'u fesili po ua tonu.
    Let me ask whether that is the correct [route].
14. Lo outou tali mua na.
    That is your first answer.
15. Ai ia Savai'i lafa-lafa—
    Then on to Savai'i which is level—
16. Na 'u'una Valua ma Tiapa.
    [A land] which Valua and Tiapa took possession of.

17. Se la'i egāse i luga ;—
[From it] a westerly wind rustles on high ;
18. E agi ma ofaga i Manu'a.
It blows and nestles on Manua.
19. Ai lau tali mua ua uga.
My first answer is ended.
20. So'u fai tala ia Manu'a
Let me [now] tell the facts ('tale') about Manu'a
21. I le Faletolu ma le Fiti-uta.
To Fale-tolu and Fiti-uta—
22. E te Aopo e, ma Asau,
You are a mixed travelling party ;
23. Tiga lou tala vavau
Notwithstanding your ancient tale
24. E te u'u mai ia te a'u
You will lay hold on me (*i.e.*, Manu'a)
25. E te fai mātua i Manu'a—
[For] your parents are in Manu'a—
26. I Fongo-olo-ula ma Malae-a-Vavau,
In Fonga-olo-ula and Malae-a-Vavau,
27. Ma Sopoaga a le to'elau.
And Sopoanga of the trade-winds.
O !

Such is the ancient *Solo*, but Tauanu'u of Manu'a the '*fale-tala*' or legend-keeper of Manu'a gave the following as the popular way of accounting for the name Savai'i.

"Savai'i and this Manu'a are one ; for Le-Fatu and Le-ele'ele peopled this Manu'a ; they two begot I'i and Sava—I'i the girl and Sava the boy, who peopled the island which is called Savai'i."

He also stated that Fatu and Ele-ele were the first pair who came down from heaven ; that they alighted at the east end of the village of Tau at a place called Malae-a-Vavau, a few minutes' walk from the teacher's house there. They gave birth to a boy and a girl named Tiāpā and Valu'a ; these went and peopled the island of Savai'i by giving birth to a girl I'i and a boy Sava ; hence the name Savai'i. Another account says that Fatu and Ele'ele were the parents of Fai-malie and Fai-tamai, Vavau and Tele *or* Nu'u and Tele, Mamao and Laveai *or* Ilu, Valu'a and Tiapa.

Notes to No. XXXIX.

Line 1. *Causing calamity;* aumamala, 'causing *mala*'; that is, any one showing disrespect to this land will perish.

3. *Sopo-le-Malama* means 'Pass-over-the-moon."

11. *Moso* is one of the heroes of the 'War of the gods and Giants,' *q.v.*

15. *Level,* lafa-lafa; that is, the island has no chief of its own.

26. *Fongo-olo-ula,* 'face-of-the-red-fort'; *Sopoanga,* 'the passing over.'

CONTRIBUTIONS to a KNOWLEDGE of AUSTRALIAN VEGETABLE EXUDATIONS. No. 1.

By J. H. Maiden, F.L.S., &c., and H. G. Smith.

[*Read before the Royal Society of N. S. Wales, September 4, 1895.*]

Under the above title we submit some notes on gums, resins, &c., which we trust will be of value, either because the exudations are entirely new to science,[1] or because, if their existence has already been recorded, their composition has not been determined. The notes are of various degrees of fullness; in some cases the substances promise to be of such interest, that we hope at some future time to deal more fully with them.

Exudations Dealt With—*Gums.*

Bosistoa sapindiformis, F.v.M.; Rutaceæ.

Melicope neurococca, Benth.; Rutaceæ.

Geijera Muelleri, Benth.; Rutaceæ.

Pentaceras australis, Hook. f.; Rutaceæ.

Capparis nobilis, F.v.M.; Capparideæ.

Acacia Oswaldi, F.v.M.; Leguminosæ.

Acacia retinoides, Schlecht; Leguminosæ.

Acacia Bakeri, Maiden; Leguminosæ.

---

[1] In the present paper all the exudations are new to science, except that of *Eucalyptus Planchoniana*.

Acacia Maideni, F.v.M.; Leguminosæ.
Albizzia pruinosa, Benth.; Leguminosæ.

Kinos.

Eucalyptus hæmastoma, Sm., var. *micrantha*, Benth.: Myrtaceæ.
Eucalyptus Planchoniana, F.v.M., Myrtaceæ.
Schizomeria ovata, Don, Saxifrageæ.

Gum-resin.

Medicosma Cunninghamii, Hook. f.: Rutaceæ.

Gums.

Bosistoa sapindiformis, F.v.M. (N.O. Rutaceæ).
Collected at Mullumbimby, Brunswick River, N. S. Wales.

This gum, which is transparent and pale coloured, does not wholly dissolve in water, although a large percentage goes into solution after some time; this is arabin. The insoluble portion dissolves in a dilute alkaline solution, which becomes yellowish in colour; this is precipitated as arabin, thus the insoluble portion consists of metarabin. There is no difference in the physical characteristics of this gum and those of the other Rutaceous gums described in this paper. Resin is absent. The amount of this gum at our disposal was not large, so that it was not possible to make further inquiries respecting it.

Geijera Muelleri, Benth. (N.O. Rutaceæ).
"Axe-breaker."
Collected at Lismore, N. S. Wales.

This gum is in large tears of a light amber to light brownish colour, transparent, with a very bright fracture. It is brittle, and although somewhat tough, powders fairly well. The fine powder, when placed in cold water, does not readily dissolve, nor does much more go into solution on boiling. The aqueous solution, when separated from the insoluble portion, has fairly adhesive properties, although the viscosity is not very high.

The insoluble portion when treated with dilute soda solution becomes yellowish and darkens slightly. On continued gentle heating the whole slowly goes into solution. The soluble portion

consists principally of the lime and magnesia salts of arabic acid, as the arabin, when precipitated from its solution by alcohol, heated with dilute sulphuric acid, the acid solution neutralised by carbonate of lime, then precipitated with hot alcohol, yields a filtrate which when evaporated to a syrup, gives arabinose.

The portion dissolved by dilute soda solution was metarabin, as when dissolved it changes into arabin. This is precipitated from the alkaline solution by the addition of alcohol. This precipitate when filtered off, washed with alcohol, dissolved in water, acidified, and again precipitated by alcohol has all the appearance of arabin. When this precipitate is heated with dilute sulphuric acid, treated in the usual way (above described), a crystallized sugar is obtained having the rhombic character of arabinose, and which when dissolved in water is dextro-rotatory. This gum may therefore be considered as belonging to the arabin group, the portion not soluble in water being metarabin.

This gum contained 17·23 per cent. of moisture, while the percentage of ash was only 1·94, which is low for a gum. The ash consisted of the carbonates of lime and magnesia, and a small quantity of potassium; it also contained both sulphuric and phosphoric acids. The colour of the ash is white. It contains a small percentage of albuminoids, as the presence of nitrogen was readily detected by the ordinary method.

When heated with strong nitric acid a large quantity of mucic acid is formed; as much as 29·98 per cent. was obtained from this specimen. The method followed in estimating the mucic acid in these gums, is to treat about two grams. of the powdered gum with about 8 cc. of nitric acid in a beaker, gently heating until a clear solution is obtained. The heat is then slightly increased until the greater portion of the acid is driven off; the remainder becomes turbid. After standing some hours, to allow crystallization to take place, about 5 cc. of nitric acid is added, the mucic acid filtered off, washed with water, dried and weighed. The filtrate (with the washings) is evaporated down, again treated

with nitric acid and the process repeated. A small quantity of mucic acid is usually obtained in this second treatment.

The portion of the gum soluble in water gives only a small precipitate with ferric chloride, nor does it give any marked reactions with mercuric chloride, stannous chloride, or with a saturated solution of borax.

The gum is interesting, primarily because it belongs to the Rutaceæ, a Natural Order very few of whose genera have, up to the present, been recorded as yielding gums. Commercially it cannot be looked upon as a substitute for gum arabic or gums of that class, as a large proportion is insoluble in cold water. The large percentage of mucic acid formed is very remarkable.

Melicope neurococca, Benth. (N.O. Rutaceæ).

Syn: (*Bouchardatia neurococca*, Baill.)

Collected at Lismore, N. S. Wales.

This gum is in large tears and globular masses of a light amber colour, very bright and transparent looking. It is brittle and breaks with a very bright conchoidal fracture. It much resembles the gum from *Geijera Muelleri*, except that this sample is more bright in appearance. It also behaves in the same way in water, a portion only going into solution, while the remainder is soluble when heated in a dilute soda solution. The precipitates of arabin and the formation of arabinose, are produced exactly in the same way as described under *Geijera Muelleri*.

Our sample contained 14·68 per cent. of moisture and 2·54 per cent. of ash; this ash is white, and consists of the carbonates of lime and magnesia, with sulphuric and phosphoric acids. Only a slight trace of nitrogen was detected, indicating the almost entire absence of albuminoids.

The yield of mucic acid in this gum was very large, no less than 42·48 per cent. being obtained. This is remarkably high. Ferric chloride in the portion soluble in water gave no precipitate, and only darkened the solution slightly. Other reagents gave no results.

Pentaceras australis, Hook. f. (N.O. Rutaceæ).

"Scrub Hickory."

Collected at Mullumbimby, Brunswick River, N. S. Wales.

The colour, appearance, and physical characteristics of this gum almost exactly resemble the gum of *Melicope (Bouchardatia) neurococca*, with the exception that the tears are slightly longer. In water a portion only goes into solution, while the remainder is soluble in dilute soda solution on heating. The solutions give the arabin precipitates, with formation of arabinose when treated with dilute sulphuric acid, as described already under *Geijera Muelleri*. A soda solution when heated becomes quite dark. No nitrogen was detected in two determinations.

The gum contains 11·12 per cent. of moisture, and only 1·73 per cent. of ash. The ash is white, and contains the same constituents as that of *Geijera Muelleri*. Ferric chloride gives no precipitate and only darkens the solution slightly. The other usual reagents gave no marked reactions. The aqueous portion possesses little adhesiveness. The yield of mucic acid is very small, thus showing an important difference from the other gums of the Rutaceæ here described.

These three gums belonging to the Rutaceæ, viz., *Geijera Muelleri*, *Melicope (Bouchardatia) neurococca*, and *Pentaceras australis*, resemble each other in a marked manner, by their solubility in water and soda, low ash, brittle nature, and bright conchoidal fracture, the latter differing from the other two by not containing albuminoids and giving only a very small quantity of mucic acid on treatment with nitric acid.

Capparis nobilis, F.v.M. (N. O. Capparideæ).

"Wild Lemon."

Collected at Woodburn, Richmond River, N. S. Wales.

This sample is in small particles, or small vermiform tears, semi-transparent, and of a horny texture, does not dissolve in cold water but swells up to an enormous extent. On boiling, the particles partly disintegrate but do not dissolve.

In dilute soda solution it does not dissolve, but partly forms a mucilagenous thick syrupy liquid, which is precipitated by alcohol as a slimy mass, but no arabin appears to form even on long boiling, neither does the solution become yellow with alkali. This precipitate when dissolved by boiling in dilute hydrochloric acid solution, is precipitated apparently as arabin by alcohol. The original swollen mass is also dissolved on heating with dilute hydrochloric acid, forming arabin, and is precipitated apparently as arabin on the addition of alcohol.

The amount of material at our disposal was too small to determine whether arabinose could be formed by treatment with dilute sulphuric acid, but the mode of formation, appearance, and behaviour of the gum to reagents, indicate that it consists almost wholly of pararabin, which does not form arabinose when thus treated. From the above it will be observed that this exudation resembles in its properties the gums of the Australian Sterculiaceæ.[1]

Acacia Oswaldi, F.v.M. (N. O. Leguminosæ).

"Miljee."

Collected at Nelyambo, Darling River, N. S. Wales.

This sample has all the appearance of ordinary commercial gum arabic; some of the pieces are colourless. In appearance, taste, solubility and reactions with reagents, it differs in no respect from gum arabic. It is however very acid in aqueous solution, and is perhaps deficient in adhesiveness and viscosity to the best gum arabic. It is identical with the gums obtained from several other species of Acacia growing in the dry western portion of New South Wales, which have great commercial possibilities, providing they are obtained in sufficient quantities. It gave no precipitate with ferric chloride, nor did it form a jelly with that reagent. It became of a lemon colour when treated with dilute soda, it gave no reaction with $HgCl_2$ nor with borax solution. This sample when examined contained moisture equal to 15·307 per cent. and ash equal to 2·21 per cent.

---

[1] *Cf.* Sterculia gum; its similarities and dissimilarities to Tragacanth. Occurrence of Pararabin in Sterculia Gum.—Pharm. Journ. [3] xx., 381.

Acacia retinoides, Schlecht. (N. O. Leguminosæ).

Sample from Victoria, kindly sent by Baron von Mueller.

This gum is in tears of an amber colour, transparent, bright and somewhat brittle. It dissolves entirely in water, the solution being slightly tinged with brown. It is fairly adhesive being of good viscosity. It gives a slight precipitate with ferric chloride, and slightly darkens to a lemon colour when heated with dilute soda. It may be considered a promising specimen of the arabin gums, unfortunately the specimen we have is too dark in colour to be of first rate quality. The other tests, usual with a gum of this class, were not carried out on account of the small amount of material at our disposal, as a portion was required for permanent display in the Gums Collection in the Technological Museum.

Acacia Bakeri, Maiden (N.O. Leguminosæ).

Collected at Mullumbimby, N. S. Wales.

Our specimens of this gum are principally in tears, very bright and transparent, dark amber coloured, very brittle and bright in fracture. It is entirely and readily soluble in cold water, and is in this respect one of the best of the coast Acacia gums of this Colony; it is very adhesive and its comparative viscosity is high. Unfortunately our samples darken much in aqueous solution. The solution is slightly acid to litmus paper. Ferric chloride gives a cream coloured solid mass exactly resembling in bulk and colour that from *A. Maideni*, and it behaves in the same way as that gum with a saturated solution of borax, mercuric chloride and basic acetate of lead. Both these gums belong to the arabin group, and if obtainable in quantity would be of some commercial value. As far as our samples show at present, the gum of *A. Maideni* has a better colour than that or *A. Bakeri*, but it is inferior to it as regards its adhesive properties. When warmed with dilute soda solution, the aqueous solution of the gum darkens considerably. The ash of this gum is remarkable in that it contains a large proportion of manganese. It contains 15·2 per cent. moisture and 3·6 per cent. ash.

Acacia Maideni, F.v.M. (N. O. Leguminosæ).

"Broad-leaved Sally."

Collected at Woodburn, N. S. Wales.

Our sample of this gum is in small pieces of a light amber colour, rather brittle, with very bright fracture, but without the dark brown objectionable portions so common in the Acacia gums, especially *A. decurrens*. When treated with cold water, almost the whole of the gum slowly goes into solution, forming a very pale coloured liquid which is very adhesive, of good body or having a high viscosity. It is however, rather tedious to dissolve. The solution is slightly acid to test paper. It forms a solid cream-coloured jelly with ferric chloride, thus showing absence of tannin. It does not thicken with borax solution, nor does it undergo any change with mercuric chloride. It gives a precipitate with basic acetate of lead. It gives a dense white precipitate with alcohol in acid solutions. It slightly darkens to a canary colour when warmed with dilute soda solution. It contains 16·15 per cent. water and 4·67 per cent. ash; the ash consists principally of the carbonates of lime and manganese and potassium, with sulphuric acid, and only the merest trace of phosphoric acid. The ash contains fusible salts and is difficult to incinerate, it contains only a trace of manganese.

Albizzia pruinosa, Benth. (N. O. Leguminosæ).

Usually known as "Stinkwood."

Collected at Cumbulum, near Tintenbar, N. S. Wales.

This sample is in small amber coloured pieces, and is very much admixed with woody matter. It is fairly transparent and breaks with a bright fracture. It is only partly soluble in water, the soluble portion being arabin; it forms a fairly adhesive liquid. It gives no precipitate with ferric chloride nor does it form a jelly, and only slightly darkens when heated with dilute soda. The insoluble portion is soluble in dilute alkalis, and is precipitated as arabin on acidifying with acetic acid and adding alcohol.

Kinos or Astringent Exudations.

Eucalyptus hæmastoma, Sm., var. *micrantha*, Benth.

(N. O. Myrtaceæ).

"White Gum," "Cabbage Gum," "Brittle Gum."

Collected at Bungawalbyn, Richmond River, N.S.W., July 1895.

This kino is freshly exuded for the most part. It belongs to the ruby group of kinos, being practically identical with the kino of the normal species described in the proceedings of the Linnean Society.[1]

Eucalyptus Planchoniana, F.v.M. (N. O. Myrtaceæ).

We have two small samples. The first was received from F. M. Bailey, F.L.S., Colonial Botanist of Queensland, and is of Queensland origin.

When received, this kino was rather dark in colour, evidently through having been collected some time. It is in small pieces, principally in portions of tears, breaks with a bright fracture, and is shiny on the outside. It dissolves in alcohol to a clear liquid, bright but dark, it is very tough and difficult to powder. It belongs to the ruby group.

Our second sample collected on the Evans River, N. S. Wales, is unfortunately also not a good sample for complete examination, since it is old and much dried up, while phlobaphenes have formed to a very large extent. From experiments independently made it falls in the ruby group, being another addition to that fairly large group of Eucalypts giving exudations that entirely dissolve when fresh in both alcohol and water. We hope to obtain a better specimen for further examination.

Schizomeria ovata, Don. (N.O. Saxifrageæ).

Collected at Evans River, N. S. Wales.

---

[1] Proc. Linn. Soc. N. S. Wales, (2) IV., p. 614.

This exudation has the appearance of kino.[1] When treated with alcohol the greater portion of the tannic acid goes into solution. This tannin gives a brownish green colour with ferric chloride, when a fairly strong solution of the kino is tested, but on sufficient dilution (in a very dilute aqueous solution), it gives a purple colour with the same reagent; an aqueous solution of the tannin was the material tested. The insoluble portion has the appearance of a gum, but is insoluble in water on heating until a small quantity of dilute soda has been added. When the original substance is treated with water the tannin dissolves, while the gum remains insoluble, but much swollen. This insoluble portion is soluble in dilute soda, and is precipitated on acidifying the solution, or on the addition of alcohol. It is thus found to be metarabin. The reactions and composition of this exudation show it to be identical with that yielded by the *Ceratopetalums*[2] and the exudations thus confirm the affinities of these trees belonging to different genera of the Saxifrageæ.

Gum Resins.

Medicosma Cunninghamii, Hook. (N. O. Rutaceæ).

The tree is locally known as "Glue Gum."

Collected at Mullumbimby, N. S. Wales.

This is a red, brittle, resinous substance with a very bright fracture, in small transparent pieces, and of a bright rather light, ruby colour. It is very brittle and readily powders, the colour

---

[1] A number of our Eucalyptus and other astringent exudations of variable composition have been called "kinos," because of their resemblance, more or less strong, to the astringent exudation of *Pterocarpus marsupium*, known in medicine as "kino." The use of the term is convenient, and is used in these papers "without prejudice." It seems to us quite unnecessary, at present, to coin another term for astringent exudations whose composition is not precisely identical with that of the original kino; we also look upon it as undesirable, until very many more have been examined, and before those who lay stress upon nomenclature of this kind are in a position to select a suitable term or terms.

[2] Observations on the gums yielded by two species of *Ceratopetalum*.—Proc. Aust. Assoc. Adv. Sci., II., 381, (1890).

of the powder being a dark pink. It was apparently very liquid when exuding, as the adherent wood and bark are varnished with it. It burns with a very smoky flame, resembling ordinary resin in this respect, and burns away almost without residue. When treated with ether the resin slowly dissolves, forming a lemon coloured solution. The powder acts in a very peculiar manner in ether, agglutinating itself at once into an elastic ball which can be stretched in the same way as caoutchouc, thus preventing the solution of the resin in the interior portions. In rectified alcohol the resin goes into solution, forming a bright orange coloured liquid, the residue not agglutinating. When the resin has been removed and the residue dried, it powders readily to a light brown colour. The resin is of an orange brown colour.

The gummy portion, after thoroughly washing with alcohol, is much swollen and somewhat elastic. When dried until of constant weight it was found to amount to 20·02 per cent. of the whole. The original substance in powder on being heated in an oven until of constant weight, 2·14 per cent. was lost : this was probably moisture contained in the gummy portion, as no volatile oil appeared to be present. The resin when evaporated to dryness and heated till of constant weight equalled 77·2 per cent, while the ash only amounted to ·2 per cent., so that the proximate constituents may be stated as

Resin	77·20	per cent.
Gummy substance ?	20·02	,,
Moisture, etc. ...	2·14	,,
Ash	·20	,,
	99·56	

The gummy portion contains some albuminoids, as indicated by the presence of nitrogen. The dried portion after separating the resin is not soluble in water on boiling in any degree ; when boiled with dilute soda it becomes brown, but only a small portion goes into solution, nor is it soluble in dilute acids. From the above it

appears that this insoluble substance contained in this resin is a body of some interest, and when sufficient of the exudation shall have been obtained, it will be desirable for its composition and constituents to be determined. For the present we are only able to describe it as "gummy substance"?

The collector (Mr. W. Bäuerlen) says that, when fresh, this exudation is exceedingly sticky, hence the local name of the tree. It is not abundant, but is widely diffused, and well known locally because of its brilliant colour. It readily stains the fingers a vermilion colour, and that, when dry, it reminded him of grass-tree gum *(Xanthorrhœa)*.

GEOLOGICAL LABORATORY NOTES—No. 1.

By J. Milne Curran.

[*Read before the Royal Society of N. S. Wales, November 6, 1895.*]

I.—On Selenium Associated with Gold and Bismuth, from Mount Hope, N. S. Wales.

Some twelve months ago I received a box of gold bearing stone from the Mount Allen Mine near Mount Hope, in this Colony. The stone was packed loosely, and on opening the case, a peculiar smell suggestive of selenium was easily detected. The same odour could be produced at any time by shaking the stones together. The material is being mined for gold, and is part of an auriferous belt of slate, interbedded with Silurian slates to the north of Mount Hope. The slate is of a rich red ale colour, and splits readily into laminae, which correspond with, or are generally parallel to the original bedding planes. Occasionally strings and knots of a harder clay-slate occur, not so bright in colour, but rather inclining to a chocolate brown. Through this last nodules of quartz are sometimes developed. So far no sulphides have

been detected in the stone, although there can be little doubt that this oxidised lode-stuff has been derived from some form of pyrites. The gold is noted as occurring in three ways.

1. In plates and patches spread out along the laminae of the slate, appearing bright and burnished-like in lustre, but in thickness hardly more than a mere film. 2. In specks and grains associated with quartz. 3. In grains and irregular masses enclosed completely in an aggregate of bismuth oxide and carbonate.

The selenium is irregularly distributed through the stone. There is no character that I could recognise, to guide one in identifying the portions richest in this rare element. Heated in a closed glass tube most of the stone gives a black sublimate with the characteristic odour of volatilized selenium. When the portions of the stone richer in selenium are so treated, the sublimate shows a red ring, inclining to crimson below the black. Any samples of the stone when rubbed briskly together emit the characteristic disagreeable smell suggestive of bisulphide of carbon.

The oxide and carbonate have evidently been derived from some mineral not now determinable. It is probable that the selenium and the bismuth existed as a selenide or a sulphide of bismuth. This sulphide or selinide of bismuth was probably auriferous, as in the case of the telluride of bismuth described by Professor David and Mr. Mingaye.[1] As work is progressing at the Mount Allen Mine we may hope for further information in regard to this occurrence of selenium.

II.—On a Graphitic Slate from Yalcogrin, N.S. Wales.

Graphitic slates crop out at a point about twelve miles north-west of Yalcogrin Station. They are interstratified with slates of Silurian age. These are again succeeded unconformably by Devonian Sandstones and quartzites. The lustrous and polished appearance of the slate would lead one believe that it contained a high percentage of graphite. It marks paper readily when

[1] Records of the Geological Survey, N. S. Wales, Vol. I., pp. 26, 29.

abraided in the direction of its cleavage. The cleavage surfaces of some of this slate are pitted with obscure markings which may prove of organic origin. On analysis the slate gives 12·5% of graphite.

III.—Analysis of Water from Wyalong.

A remarkable feature in the Wyalong goldfield is the great depth to which the prevailing rock, granite, is decomposed. Shafts have been put down to a depth of one hundred and fifty to one hundred and ninety feet through a granite decomposed *in situ*. A tract of country of this description must absorb a large percentage of the rainfall. with little chance of an outlet underground to completely drain the saturated decomposed rock. Mr. Farant Cox found a very considerable supply of water sufficient for a six foot Huntingdon mill without making any impression on the available supply. The water was highly mineralised, and as one would expect, holds in solution magnesia, lime, soda, and potash. A preliminary examination showed that the water held close on 2,000 grains of total solids per gallon. A careful analysis in duplicate was made by my former assistant Mr. James Petrie and myself.

Analysis of water from shaft at Cox's Huntingdon Mill, Wyalong.

Silica	37·268
Alumina	3·052
Lime...	43·540
Magnesia	109·144
Soda...	551·236
Potash	6·188
Sulp. trioxide	192·430
Chlorine	924·784
Water of crystallisation	209·300
	2076·94
Less O equiv. of Cl.	208·39
	1868·55

The water contained traces of zinc and large quantities of "soluble" organic matter. The large percentage of sodium and chlorine opens up the question as to whence this sodium chloride —as it exists in the water—was derived.

IV.—On the Trachytes of the Canoblas and the Warrumbungle Mountains.

The first reference to a trachyte from the Warrumbungle Mountains that I can find is a note by the writer.[1] This typical trachyte was described as coming from Timor rock. Subsequently a trachyte from the Coonabarabran district was described by Mr. G. W. Card.[2] I do not know that any record has been made hitherto of a trachyte from the Canoblas near Orange. About six miles west of Coonabararan there is an isolated hill some eight to nine hundred feet in height. The weathering of the rocks on its sides is quite suggestive of the trachytes of the Drachenfels. The base of the hill is composed of a grey trachyte that in hand specimens shows a mottled appearance. Under the microscope the rock shows an abundance of sanidine, and the mottling is due to aggregates of "blue hornblende" that abound in the rock. An exactly similar rock is found on the Canoblas near Orange, on the eastern slopes of the mountain above Mr. George Plowman's farm. Both at Timor and on the Canoblas I have seen sufficient to convince me that these trachytes are older than the basalts and more basic lavas that abound in those districts.

About half way up Timor the character of the trachyte changes. The rock is there of a dull green colour with a shade of yellow. Abundant needles of sanidine are seen glistening in the rock. The microscope shows a decided flow structure, and a constitution corresponding to a typical trachyte.

About ten miles to the north of Coonabarabran there is a hill of a compact trachyte that breaks with a fracture not unlike quartzite. Under the microscope the rock shows as composed

[1] Proceedings Linnean Society, N. S. Wales, Vol. ix., p. 467, Series 2.

[2] Records of the Geological Survey of N. S. Wales, Vol. iv., p. 115, pl. x.

almost wholly of sanidine, so disposed as to be described as a panidiomorphic sanidine trachyte. I exhibit micro-photographs of the rock herewith. Some of the Canoblas rock resembles this trachyte. On the western slopes of the Canoblas a wall of trachyte, standing some fifty feet above the surface, can with difficulty be distinguished from the same rocks at Coonabarabran.

Associated with the trachytes of Timor is a rock that I can only describe as an enstatite-andesite. A rock similar to this too is largely developed on the Canoblas. I am at present engaged on an exhaustive examination, chemical and microscopical, of the rocks mentioned herein, and take this opportunity to record their occurrence, and exhibit characteristic photographs.

In addition to the rocks named, I exhibit a fine specimen of the acidic lava known as rhyolite from the Canoblas. It is the first example I have met of a rhyolite *in situ* amongst Tertiary rocks in Australia. Rolled blocks of a somewhat similar rock are found in the Tumberumba valley.

On the OCCURRENCE of ARTESIAN WATER in ROCKS other than CRETACEOUS.

By Edward F. Pittman, A.R.S.M., Government Geologist, N.S.W.

[*Read before the Royal Society of N. S. Wales, December 4, 1895.*]

In September last I had the honour to report, to the Hon. the Minister for Mines, the discovery of palæontological evidence proving that artesian water occurs in rocks of greater age than the Lower Cretaceous sediments, to which it had hitherto been supposed to be confined, and the object of the present paper is to place upon the records of this Society a brief account of the facts referred to, together with some additional evidence gathered dur-

ing a recent trip through parts of Queensland and New South Wales.

The railway now in course of construction between Narrabri and Moree passes over black-soil plains, on which there is no permanent water supply which could be utilised for the locomotives, and it was an enquiry by the Railway Commissioners as to whether there were any prospects of obtaining artesian water at Woolabrar, on Dobikin run, about midway between Narrabri and Moree, which led to my making an examination of this country. The rocks penetrated by wells on the Dobikin run were found to consist of white and greyish sandstones, bluish-grey sandy shales, brownish clays, and nodules of clay ironstone. A characteristic feature of these sediments was that they crumbled or became disintegrated freely on exposure to the atmosphere, owing no doubt to the quantity of water contained in them. In these rocks were found numerous plant impressions, amongst which *Taeniopteris Daintreei*, (McCoy), a fossil plant characteristic of the Mesozoic coal measures of Victoria, the Clarence River series of New South Wales, and the Ipswich coal measures of Queensland, was readily recognizable. Another plant from this locality was identified by Mr. W. S. Dun, Assistant Palæontologist to the Geological Survey, as belonging to the genus *Baiera*.

Similar rocks were observed on the Terry-Hie-Hie run, about twenty-five miles to the north-east, and still further north at an old shaft known as Moloney's well, fourteen miles east of Moree, *Taeniopteris Daintreei* was again obtained. On arriving at Moree an examination of the drillings showed that, in their lithological characters, the rocks penetrated by the bore very strongly resembled those met with at Dobikin and Terry-Hie-Hie, and a subsequent examination of the contents of the core-box in Sydney, enabled me to detect *Taeniopteris Daintreei* in one of the few solid pieces of rock which had been obtained by 'reaming,'—the greater part of the drillings having been extracted in a fine state of division, owing to the percussive action of the Canadian drill.

The evidence thus obtained proves beyond doubt that the Moree bore, which yields about three million gallons per day of artesian water of very good quality, is not in the Lower Cretaceous rocks as was previously supposed, but in rocks of the same age as the Ipswich beds of Queensland, the coal measures of Victoria, and the Clarence River coal measures of New South Wales.

In subsequently examining the core-box from the Coonamble bore, I identified, in a solid piece of 'reamings,' a specimen of *Taeniopteris Daintreei*, and one of *Thinnfeldia odontopteroides*, Morris, another fossil plant characteristic of the Hawkesbury series, which are regarded as homotaxial with the Clarence series. The Coonamble bore yields a supply of about one million, eight-hundred thousand gallons of artesian water per day.

On the 20th January, 1894, a paragraph appeared in the *Daily Telegraph*, stating that the Revd. J. M. Curran had furnished a report to the Minister for Works to the effect that in his opinion the rocks pierced by the Coonamble bore were Triassic and not Cretaceous. Enquiries recently made at the Works Department elicited the reply that no such written report had ever been received from Mr. Curran, but I understand that our respected President, Professor David, questioned Mr. Curran at the time, as to his reasons for supposing these rocks to be Triassic, and his reply was that although he had no definite palæontological proof of the age of the rocks, his opinion was based upon their lithological resemblance to those of the Dubbo district with which he was familiar, and upon the occurrence of a number of indeterminable plant remains, similar to those common in the Dubbo beds.

In 1891, Mr. Robert Etheridge, Junior, identified a specimen of *Taeniopteris Daintreei* from the Nyngan bore, and during the present year, Mr. W. S. Dun recognized another specimen of the same fossil plant in some rocks forwarded by Mr. W. L. R. Gipps, from Terabile Creek, four and a half miles from the Castlereagh River.

It is clear therefore that a large portion of the area hitherto regarded as Lower Cretaceous, is in reality occupied by rocks of

Triassic or Jurassic age, and it is also proved that these rocks are artesian-water-bearing, and that they extend much farther to the eastward than the eastern boundary of our artesian basin, as tentatively laid down on the geological map of the Colony. It may here be remarked that it is only by information derived from bores and wells that the age of the underlying formations can be determined in most of the country hitherto referred to, for the reason that it consists of plains, the surface of which is covered by Pleistocene and recent deposits.

I have recently returned from a trip through part of Queensland, and that portion of New South Wales lying to the north and north-west of Inverell, the object of my visit being to trace and map the eastern boundary of this newly discovered artesian-water-bearing basin. I find that on the Dumaresq River (the northern boundary of the Colony), it passes about fifteen miles to the west of Texas, and I have, so far, traced it in a more or less south-westerly direction to the neighbourhood of Wallangra, the dip of the beds being to the west or south-west. If this boundary be assumed to continue so as to take in the Coonamble and Nyngan bores, it will easily be realized that a very considerable addition must be made to the area of the New South Wales artesian basin as hitherto shown on our geological map.

But if the discovery of artesian water in rocks of Triassic or Jurassic age be a matter of importance to New South Wales, it is, I think of still greater importance to the colony of Queensland. Mr. R. L. Jack, the Government Geologist of that Colony, and his assistant, Mr. A. Gibb-Maitland, were engaged, during the year 1894, in mapping the outcrop of the basal or intake beds of the Lower Cretaceous basin of Queensland. They found these beds to consist of very porous (bibulous) marine sandstones which Mr. Jack has named the Blythesdale Braystone, and which he described in detail in a very interesting paper read before the Australasian Association for the Advancement of Science, at its Brisbane meeting in January last.[1] Specimens of this Blythesdale Bray-

[1] See also "Artesian Water in the Western Interior of Queensland," Bulletin No. 1—Geological Survey of Queensland, 1895.

stone are exhibited on the table. The outcrop of this rock was traced from near Texas to Roma, following a more or less north-westerly course, but overlaid in places by the Desert Sandstone, (Upper Cretaceous).

The most southerly portion of this outcrop is described by Mr. Jack as differing somewhat from the typical Blythesdale Braystone as seen on the Weir River, and at Roma and other places further northward. The rock to the west of Texas is a gritty sandstone, and it contains cementing material, which appears to be absent from the typical Braystone; the latter is also, as a rule, much finer grained.

I have inspected the Braystone beds in the neighbourhood of Roma and Blythesdale, and I have also seen the sandstones fifteen miles west of Texas, and am strongly of opinion that the latter belong to freshwater beds of Triassic or Jurassic age—in other words to the Ipswich measures, and not to the marine beds of the Lower Cretaceous (Blythesdale Braystones). I have, as already stated, traced these gritty sandstones without any sign of a break in their continuity, from the point fifteen miles west of Texas to Wallangra, and from the spoil heap of a well, ninety feet deep, twelve miles south-west of Yetman, I have obtained impressions of the fossil plant *Teniopteris Daintreei*. Samples of the sandstones from the west of Texas, and from the south of Yetman are exhibited for comparison.

In his paper read before the Australasian Association for the Advancement of Science, Mr. Jack describes the Blythesdale Braystones as the intake beds of the Cretaceous basin, but he adds that he strongly suspects they "may be reinforced by the agency of strata geologically on a lower horizon." He goes on to say, "Till lately the best information available led me to the belief that the Trias-Jura formation, or Ipswich coal measures was succeeded conformably by the Lower Cretaceous or Rolling Downs formation, but in the last trip I have seen unmistakable evidence of an unconformability between them. It may be that the bibulous

lower members of the Cretaceous rest directly on sandy members of the Ipswich coal measures which dip in the same direction. In this case the sandstone beds above the Toowoomba basalts, and the Murphy's Creek beds below, would feed the Blythesdale Braystones, and still further tend to equalize the supply by making good the loss entailed by the supposed connection of the latter with the ocean."

Up to the present time, however, no bores in search of artesian water have been put down in the Trias-Jura rocks of the Downs to the north-east of the line of outcrop of the Blythesdale Braystone. Two bores have been put down in the Ipswich coal measures to the east of the Dividing Range, but neither of them was very successful. The site of one of these bores was Eagle Farm, near Brisbane racecourse, and here an artesian supply of about eight thousand gallons of inferior water per day was obtained. The other bore was at Laidley, fifty-one miles west of Brisbane, and it did not result successfully, so far as obtaining an artesian supply. It appears to me, however, that the positions of both these bores were unfavourable. The coal measures at Eagle Farm appear to be, to all intents and purposes, isolated from the main body of the Ipswich coal measures which underlie the Downs; for a large part of the city of Brisbane is built upon hills of palæozoic schists, against which the coal measures thin out, and which act as a barrier between those on the east, and those on the west of Brisbane; the Laidley bore, also, does not appear to be favourably situated, when its altitude and that of the intake beds are taken into consideration.

With the country, however, to the west of Toowoomba, the conditions appear to me to be very different. Murphy's Creek railway station, to the east of Toowoomba, is 788 feet above sea level, and from there up to the top of the Dividing Range near Toowoomba, are seen, at elevations increasing up to about 2,000 feet, outcrops of sandstones of the Trias-Jura formation, with some supposed interbedded lavas. Some of these sandstones, (samples of which are exhibited) are very porous, and are therefore well

adapted to act as intake beds for artesian water. Their dip is to the west, under the Downs, at angles varying from 2° to 20°, and the rainfall over the area of their outcrop is high, being about forty inches per annum. Continuing now along the western railway line we find that there is a gradual fall in the surface of the Downs between Toowoomba and Roma, which is situated two hundred and seventeen miles further west. Thus while the altitude of Toowoomba railway station is 1,921 feet, that of Roma is 978 feet.[1] The altitude of Gowrie Junction, only seven miles west of Toowoomba is 1,577 feet, or only slightly more than that of Spring Bluff, where the porous sandstone, a specimen of which is exhibited, outcrops.

It appears to me, therefore, that there is an area of country having a width of about two hundred miles and lying to the east of the outcrop of the Blythesdale Braystone, which, though hitherto unprospected, possesses all the conditions which are regarded as necessary to the occurrence of artesian water, and in view of the recent discovery of a fine supply at Moree, in rocks of the same age as the Ipswich coal measures, I am of opinion that the probabilities of artesian water being obtained in large quantities, to the east of the outcrop of the Blythesdale Braystone, are very strong indeed.

I have already quoted from Mr. Jack's paper read before the Brisbane meeting of the Australasian Association for the Advancement of Science, in which he drew attention to the porous nature of certain beds in the Trias-Jura formation, and to the probability of the water absorbed by them reinforcing the artesian supplies of the Lower Cretaceous formation. I not only concur in this opinion but would even go so far as to suggest that the porous strata of the Trias-Jura formation may constitute the *chief* storage beds of the artesian water supply of Australia.

I am inclined to think that many of the successful bores in both New South Wales and Queensland may have obtained their

[1] Queensland Railways, Time Table.

artesian water, not altogether in the Lower Cretaceous rocks, but partly, and perhaps largely, in the underlying Ipswich coal measures. Mr. Jack, in the interesting paper already quoted, speaks of unmistakable evidence of an unconformability between these two formations, and, in a sketch section, shows this unconformability to be so strong as to interrupt the continuity of the Trias-Jura formation ; but bearing in mind the very large area which the Ipswich coal measures are known to occupy (with a more or less westerly dip), in the eastern portions of New South Wales and Queensland, and in view of the fact that at Leigh's Creek, near Lake Eyre, in South Australia, coal bearing rocks have been identified by Mr. R. Etheridge, Junr., as the probable equivalents of the Ipswich coal measures,[1] I consider that there are good reasons for believing that these Triassic or Jurassic coal measures may be *continuous* under the Lower Cretaceous basin.

The occurrence of seams of coal in many of the artesian bores in both Queensland and New South Wales, is also a matter which appears to bear upon the probability that, in many cases, sediments which have been regarded as Lower Cretaceous may really belong to the Ipswich coal measures. So far as I am aware the Rolling Downs formation, in those localities where *undoubted* sections have been examined, is essentially a marine deposit, and it appears more probable, therefore, that the coal seams intersected in many of the bores, belong to the Ipswich beds, which we know to be coal bearing, than to the Lower Cretaceous beds.

In the interests of geology it is to be hoped that bores will soon be put down with drills capable of extracting a solid core, which would settle many of the vexed questions in connection with the geology of our western districts.

---

[1] "Reports on Coal-bearing area in neighbourhood of Leigh's Creek," by H. Y. L. Brown, Government Geologist of S.A., Adelaide 1891.

NOTE ON THE ORIGIN OF MALACHITE.

(Observations made in an abandoned Copper Mine.)

By Edgar Hall.

(Communicated by Prof. Liversidge, M.A., F.R.S., &c,)

[*Read before the Royal Society of N. S. Wales, December 4, 1895.*]

It is now generally conceded by mineralogists that the oxidised portions of mineral lodes represent merely the weathered condition of the originals, and that the oxide, carbonate and sulphate minerals contained therein have been formed by atmospheric influences alone. Very few men of experience in the every day working of mines now think those influences to have been abnormal at any time. All the phenomena can be explained by the changes which are still going on, and present atmospheric conditions are ample to produce the weathering seen at the largest of mines. Such being the case, abandoned mines offer an interesting field of study to a mineralogist, as their workings expose large surfaces to the action of air and water.

Numerous as are the abandoned mines of New South Wales, the number available for examination and likely to yield valuable information, is small. This is due to two reasons; one is, that the mines have not been abandoned long enough, and the other, that most of the mines are situated in the eastern coast ranges where the rainfall is high, and consequently the mines get filled with water to a point very near the surface. It is obvious that a comparatively arid climate, or one where long periods of dry weather alternate with intervals of heavy rainfall, is required to produce large masses of oxidised ore bodies. Such a climate obtains in our far western districts, and accounts for the large bodies of oxidised ores found at Broken Hill, Cobar, and other well known places.

In such a climate oxidation proceeds very rapidly. Iron pyrites where occurring in large quantity will, in four or five years, pro-

duce such a plentiful crop of crystals of iron sulphate that the sides and floor of a drive will be covered as if by snow ; so much so that the sound of one's footfall is muffled as one proceeds.

The writer had occasion, a short time ago, to visit the abandoned workings of a copper mine, and the observations made there are the subject of this note. The mine in question is situated at Girilambone, in the western part of the Colony, about one hundred miles from the Darling. The ore occurs as a copper-bearing schist, and where unaltered is a bluish micaceous rock, carrying strings and blebs of a pyrite poor in copper. Permanent water stands at a depth of one hundred and eighty feet ; above this level the rock is soft and weathered, and the copper occurs as azurite and malachite, with a little oxide of copper. Copper glance is said to have been found there in the early days.

The azurite and malachite occur mainly as nodules of varying size ; these are not pure carbonate of copper, but are earthy, and consist of portions of schist which have been saturated with the mineral. Malachite occurs also as narrow strings of pure carbonate of the fibrous variety. It is to this I wish to draw particular attention.

Between the surface and water-level a great deal of excavation has been made in the schist, and these excavations can now be examined in safety. Most of them have been standing so for thirteen years past. The workings are very dry and crystals are not very plentiful, but in one crosscut, where there appears to be a drainage channel, the sides and roof are covered with particularly fine and long crystals of sulphate of copper and sulphate of iron, some of the crystals being an inch and a half long.

Further investigation shewed that the schist in the crosscut was full of crystals of copper sulphate. The crystals had formed in the foliation planes of the schist, and were closely packed bundles of very fine fibrous crystals, completely filling the fissure. In most cases the crystals were at right angles to the sides of the fissure, but in some cases the fibrous crystals had become curved

and had forced a layer of schist outwards into the drive. The crystals were of a brilliant blue colour, and of course were very brittle, but in other respects the resemblance to fibrous malachite as seen in the schist at other places in the mine was complete.

The resemblance at once suggested the origin of fibrous malachite, namely, that it is a pseudomorph after sulphate of copper. The ordinary text-books of mineralogy seldom hint at the method of formation of minerals, and in the case of malachite the writer has so far been able to find only one explanation of its formation. Frank Rutley[1] suggests that the mineral "has in most cases resulted from the percolation of water through copper-bearing rocks, and the subsequent deposition of the dissolved carbonate in fissures and cavities." This explanation seems improbable in view of the insolubility of copper carbonate. Watt[2] states that the basic carbonate requires a pressure of four to six atmospheres for solution in water containing carbonic acid. Such pressures are impossible under natural conditions at the short distance from the surface within which malachite is found. The deposition from solution also presupposes the formation of the carbonate from the chalcopyrite which must have formed its starting point, and this presents equal difficulties.

The production of sulphate of copper from cupreous pyrites is the first and simplest result of oxidation, and from sulphate of copper any soluble carbonate will, at ordinary temperatures and pressures, produce a basic carbonate of the composition of malachite. Verdigris, the product of slow oxidation of metallic copper in moist air at ordinary temperatures, also has the composition of malachite, but it is hardly likely that the alteration of cupreous pyrites will follow that route.

Given the oxidation of cupreous pyrites by surface influences, and the formation of fibrous crystals of sulphate of copper in cavities of a lode during a prolonged period of dry weather, it is easy to understand that during an ensuing period of wet weather,

---

[1] Mineralogy, p. 211. [2] Dictionary of Chemistry, New Edition.

the descent of waters from the surface charged with carbonic acid and carbonate of lime, will change the sulphate crystals into malachite; and that this alteration will proceed without change of form is highly probable. That this has been the mode of formation of the fibrous malachite in the cupriferous schists of Girilambone the writer has no doubt whatever, and he believes that the explanation will hold good for all occurrences of the mineral.

The following is suggested as the series of changes which have produced the carbonates of copper:—

I. A period of wet weather during which the rocks and ore formations within surface influences become saturated with, and all cavities full of, water.

II. A period of dry weather. At first the excess of water drains off rapidly, leaving the rocks merely wet all through. As the drying proceeds oxidation of the damp minerals goes on very fast and sulphates are formed. The flow of water is insufficient to carry these far, so they saturate part of the adjacent earthy minerals, and also effloresce in cavities, particularly where there is a current of air. Finally at the end of the dry period the sulphates will be left as such, forming quite dry mixtures with other substances, and incrustations or crystals in cavities and fissures.

III. Another wet period arrives. At first the descending water permeates slowly and is saturated with carbonic acid and soluble carbonates, the slow soaking of which over the dry sulphates converts the latter into carbonates. As the volume of water increases, the CO_2 and soluble carbonates become less, but the sulphates will have been already converted into carbonates, so they are not dissolved. Finally the rocks become saturated with water, the wet period passes away, and another cycle of change commences.

Every cycle will add fresh layers of carbonate to the incrustations, and fresh crystals to the fibrous bundles in the cavities, until at last solid masses of concretionary and fibrous crystalline malachite result.

A COMPARISON OF THE LANGUAGES OF PONAPE AND HAWAII.

By the late Rev. E. T. DOANE;

With additional notes and illustrations by SIDNEY H. RAY,

Memb. Anthrop. Inst., London.

[*Read before the Royal Society of N. S. Wales, September 5, 1894.*]

CONTENTS OF PART I.

1. Introduction.
2. Sounds.
3. Syllables.
4. Accent.
5. *O* emphatic.
6. *La* directive.
7. Prepositions.
8. Nouns.
9. Adjectives.

CONTENTS OF PART II.

10. Numerals.
11. Pronouns.
12. Verbs.
13. Participles.
14. Verbal directives.
15. Syntax.
16. Comparative Vocabulary.

PART I.

[This paper was sent to me by the Rev. C. M. Hyde, D.D., of the Hawaiian Evangelical Association in Honolulu. It was written by the late Rev. E. T. Doane, who was for many years a missionary of the American Board of Congregational Foreign Missions, not only in the Caroline Islands, but also in the Marshall Islands. Referring as the notes do, to a portion of the Oceanic world which is comparatively little known, they will probably be found of some value. Mr. Doane's language has in a few instances been abridged, but without in any way altering the views he has set forth. My own additions are in every case inserted either within square brackets or as foot-notes. Quotations from Alexander's Hawaiian grammar are distinguished by inverted commas.]

§ 1. INTRODUCTION.

Ponape is one of the most important islands of the Micronesian Archipelago. It claims this eminence not in population or geo-

graphical position, for there are other islands more populous and of greater commercial importance, but rather in the language, which is in vocables the fullest, and in grammar the most complete.

Micronesia is situated in the eastern portion of the great Malayan island realm, lying there as in a broad gateway through which it has received the population which now covers its sunny atolls and volcanic islands. It embraces three important groups of islands, the Caroline, Marshall, and Gilbert, with not a few widely separated coral islets. A fourth group, that of the Ladrones, would be added had not its pure native population, and so its language, been exterminated. The enumeration of these different groups may suffice for any more definite description of the whole archipelago, yet if more be needed, we may say that the whole is grouped between 2° S. lat. and 20° N. and 130° and 178° E. long. Within these lines two important tongues are represented: the one Polynesian which may be called the Polynesio-Micronesian, and which finds its habitat mainly in the Gilbert Group, taking in some atolls near the line, with perhaps a preponderating influence in the volcanic islands of Yap, the Palaus and the Ladrones. The other may be called Malayo-Micronesian, and is represented mainly by the dialects spoken in the Marshall Group and the islands lying west of this, and throughout the larger part of the Carolines, from Kusaie to Uoleai. A paper prepared some time since treated of the relationship of the Ponape to the Malay tongue.[1] In this paper it is proposed to take the same Ponape dialect and note what are its relations to the Polynesian tongue, and especially to that spoken by the Hawaiian people. Probably the larger number of those to whom this question may be put as to what is this relationship would reply, 'Just none at all, or only that of the most nebulous sort.' They would reply that in the migration of the people either from east to west, or from west to east, there is no connection between the two languages. One is Polynesian, the other Micronesian,

[1] This has apparently been lost.

would be the conclusive answer. Let us see what other answer can be found.

In this research we begin with the rulers of all language, the sounds, or the characters rather by which those sounds are set forth. And here it may be remarked that all through this discussion the Hawaiian Grammar of Andrews and Hale's work on the Polynesian tongue will be our authority.[1]

§ 2. Sounds.

The Hawaiian Grammar gives us the characters representing the pure sounds of the language when first reduced to writing, and as further distinguished from characters afterwards introduced to represent newer sounds brought in by a wider contact with the civilized world. There are twelve of these characters in all, seven for consonants and five for vowels. Those for the vowel sounds are the common European *a*, *e*, *i*, *o*, *u*; those for the consonants are the English *h*, *k*, *l*, *m*, *n*, *p*, *w*. The vowels are almost uniform in their sounds, Mr. Hale remarking "the changes that do take place are occasioned not by different shades of sounds in the vowels themselves, but by the influences of the consonants."

Of the Ponape sounds and characters it may be said that the vowels are far from possessing such uniformity. There are the usual five long vowels, then as may short, then of the vowel *o* there are three additional sounds, of *a* one, of *e* one. The consonants, however, possess much the same sounds as exist in Hawaiian, thus: *ng*, *.j*, *k*, *l*, *m*, *n*, *p*, *r*, *t*.

Tabulated the two systems stand thus:—

Consonants.		Vowels.	
Hawaii.	*Ponape.*	*Hawaii.*	*Ponape.*
Labial p.		a	ā (*long*), ă (*short*), a (*as* u *in nut*)
Dental l.	t, r, l.	e	ē (*long*), ĕ (*short*), e (*as in there*)
Nasal m, n.	m, n, ng.	i	ī (*long*), ĭ (*short*)
Guttural k.	k	o	ō (*long*), ŏ (*short*), o (*in or*), o (*in come*), o (*in wood*)
Aspirate h.	.	u	ū (*long*), ŭ (*short*).
Sibilant .	j		

[1] I have added where necessary, a few notes from more recent works.

On this table it is necessary to remark that Hawaiian *h* is *h* aspirate. Ponape possesses no such character, but *h lene* is not an unusual sound. Both tongues are alike in the use of *k*, save that occasionally the Hawaiian presses on it *t* dental, *Kauai* becoming *Tauai*, while Ponape softens *k* to *ng*, especially when the guttural is preceded by its own letter. Thus *rok ki* is pronounced *rong ki*. Hawaiian *l* often becomes *r*. There is no change in Ponape. *M* and *n* hold their usual powers in both tongues.[1] The labial *p* is also common to both, though *p* of Ponape is often softened to *m* when *p* precedes itself. Thus *kap pul* (yam soft) is pronounced *kam pul*. *W* in sound is common to both languages, but in Ponape is unsatisfactorily represented by *u*. *J*, *t*, *r*, find no place among the pure Hawaiian sounds, though afterwards introduced.[2] In Ponape *ng* is manifest and common; but in Hawaiian has passed into *n*.[3]

In the vowels there is a wider diversity between the two tongues. This may be accounted for by the finer ear of the Ponapean. His language is vocalic, but this fact is not a radical break between the languages.

§ 3. Syllables.

In Hawaiian a syllable may consist of a single letter or vowel, thus:

a, *prep.* of	i, *adj.* stingy.
a, to burn, as fire	o, *prep.* of
e, *adv.* yes	o, to stab
e, to enter	u, to rise on tiptoe
i, to speak	u, grief

All this is purely Ponapean; thus:

a, *pron.* his	i, sail	u, to rise up

[1] The writer has not noticed the nasal *m*, represented in Ponape at first by *mw* and now by *mu*. This sound is common in Melanesia.

[2] The Ponape *j* represents sounds which may be represented by the English *j* in jump, *ch* in chin, and is nearly *sh* or *ts*.

[3] Ponape has also the sound known as the Melanesian *q* (really *kpw*, but with one of the elements obscured). It was written *pw*, *mpw*, now *pu*.

a, but	i, *pron.* he	o, locative
e, *pron.* he, she, it	o, and	u, a hill

In Hawaiian, again, a greater number of words is formed by the union of a consonant and a single vowel; as, *ha*, *ka*, *li*, *me*, *no*, *pu*, *ua'*.[1] But this again is Ponape, thus, *ka*, *la*, *ma*, *ta*, *ua*, *pa*, *re*, *po*.[2] The great majority of radical words consist of two syllables both in Hawaiian and Ponapean.

Haw. *po-no*, good, *i-no*, bad, *lo-a*, long, etc.
Pon. *tu-ka*, tree, *na-na*, mountain, *ma-tau*, ocean, etc.

The Hawaiian Grammar discusses the various ways in which words are formed, some by doubling the first syllable of the root, others by doubling the second syllable. It shows also that a numerous class of words are formed by repeating both syllables or by reduplicating the root, thus:

pala, to paint, *pala-pala*	*lawe*, to carry, *lawe-lawe*
pulu, wet, *pulu-pulu*	*helu*, to count, *helu-helu*.

This is also characteristic of Ponape.

koma, to punish, *koma-koma*	*tang*, to run, *tang-tang*
monga, to eat, *monga-monga*	*pe*, to fight, *pe-pe*.

We need not dwell further upon this point. The Hawaiian Grammar, however, notices as "a peculiar trait" of the Hawaiian language, that a majority of words can be used as nouns, adjectives, verbs, or adverbs. This "peculiar trait" is also found in the Ponape tongue, and the same is true of its parts of speech.

§ 4. Accent.

The tone syllable of most Hawaiian words is the penultimate. To this there are a few exceptions. In some the tone falls on the ultimate, in others on the ante-penultimate. Suffixed particles possess great power in attracting towards them the accent. This is also the simple law of the Ponape tongue in its accentuation.

---

[1] Four; a baler; to strangle; with; to belong; trumpet; time or season.

[2] These; away; storm; what; flowers or fruit; hand; grass; smell.

In almost the opening sentence on word-making the Hawaiian Grammar states, "Every Hawaiian syllable ends in a vowel," and further, "No Hawaiian without a special effort will attempt to pronounce two consonants together," the one following the other. As this is a very striking feature of the Polynesian tongue, is there any feature in the Ponape corresponding to it?

In the first place a large part of the two-syllable words in Ponape, begin and end with a consonant:

pit, quick, *pit-pit* — *mat*, soft, *mat-mat*
tik, small, *tik-tik* — *mot*, to need, *mot-mot*.

Now for a Hawaiian to utter these words would be very difficult *i.e.*, to utter them as they stand, and so would it also be for a Ponapean. But the language delights in soft sounds, and the Ponapean delights in the legato. For him to say *tik tik*, *mot-mot*, *mat-mat*, with the full hiatus between the syllables would be almost impossible, and he never attempts it. But skilfully throwing out a string piece, a stretcher, as it were, or euphonic vowel, as *tikitik*, *motomot*, *matamat*, he glides from point to point with the utmost ease. Every Ponape word does not end in a vowel, as is seen in some of those given above, but many Ponape words end in consonants, which are largely semi-vowel, a great help to any vowel-istic speaking people. From this we see how easy in a comparative sense the Malayo-Micronesian dialects can be made to adapt themselves to such organs of speech as the Hawaiian possesses, and how near, too, the languages are in this ability to enunciate them.

§ 5. "*O* Emphatic.

The Hawaiian Grammar opens the subject of etymology by a description of the "*O* emphatic." Its position in the sentence is unique. Untranslateable as a particle, it is yet indispensable to the language. Thus:

Make o kahekili ma Oahu. — Kahekili died at Oahu.
Holo aku la o Lono. — Lono sailed away.
Alaila malu o Maui. — Then Maui will be at peace.

This character without doubt is found in the Ponape dialect, becoming not *o* emphatic, but *o* locative, an office not very dissimilar to its Hawaiian use. It is used to point out, or as one may say to locate persons or things. Of a canoe it would be said, if far away, *war o*, the canoe yonder in the distance. So of a man *ol o*, so of some subject under discussion which has been remarked about, then dropped, the thought *o*. As a locative, in the plural it is suffixed to the root letter of the particle of plurality *kan*, thus. $k + o = ko$ or *ako* with prefixed vowel, and in use stands thus: *war ako*, the canoes yonder, *jop ako*, the ships yonder, *ran ako*, the days passed away.

In Ponape this particle often adds to its power of location and becomes almost an adjective meaning 'same,' as *war o ta*, the canoe yonder, the same one seen but a little while before; *aramaj o ta*, the same person disappearing has reappeared; *likau o ta*, the same cloth shown a little while since. Such are the offices to which *o* locative is appointed in the Ponape dialect. Possessing a little less or a little higher power than "*o* emphatic" in Hawaiian no one would for a moment doubt but that the two are one and the same particle. It was so recognised by the Rev. L. H. Gulick.[1]

[The Hawaiian particle *o* is of course the same as the common Polynesian *ko*, Samoan *'o*, used principally with absolute nominative cases of nouns in an assertive sense. The only Melanesian language which employs it in this sense is the Fiji, but as a demonstrative the word is very common throughout the Melanesian region. *Cf.* Neugone, *o re koe*, the ship, a certain known ship; Aneiteum, *aien aig ko*, that same yonder is he, *ko*, an affix meaning yonder; Tanna, *nadi igo*, that thing, *in igo*, that there; with the Ponape examples above. Dr. Codrington[2] gives *ko*, *ka* or *o* as a demonstrative particle in the New Hebrides, Arago and Santo; in Bank's Islands, Gaua, Vanualava, and Motlav. The Solomon Islands Ulawa *ho* is probably the same. The Fiji has the particle

[1] Ponape Grammar, p. 20.

[2] Melanesian Languages, p. 105.

nasalized as *nggo (qo)* equivalent to "this," or "here." In Mota it appears as an article *o tanun*, the man.]

§ 6. *La* Directive.

Closely allied to *o* emphatic, not in office but as an important particle is the word *la*. In Hawaiian it is "a beautiful expletive" accompanying all verbal directives. It is said also to have "a slight reference to locality." Its position in the sentence changes the accent.

In Ponape the same particle meets us, not the same merely in orthography but often in similar uses, as well as in dissimilar, though the latter by no means negative its uses in similarity. In Ponape *la* seems often in its uses to be merely an "expletive," it often has reference to locality, it largely affects the accent when suffixed, but its more important use is as a directive, putting things to the farthest extreme of time and space. It at times seems to give to the verb a passive power; thus, *a me la*, he is dead, *a o la*, it is broken; but these passive sentences can easily be referred to *la* as directive.

[The particle is of common use in the Polynesian dialects. In Samoan *la* is "there," and *ra* is used in the same way in Rarotongan and Tahitian. In Nukuhivan *na* is used like the Hawaiian *la*, and the Mangarevan *ara* is used both of place and time. In the Melanesian languages *la* is used as a demonstrative, chiefly relating to place, pointing to an object as this, or that, to a place as here or there. The degree of nearness or remoteness indicated varies in different languages, but the demonstrative character of the word is plain. In the following table I give a summary of the forms found.

Simple—

1. Pointing near, ("this," or "here") *la, lo, le.*
2. Pointing far, ("that" or "there") *la, lo, li.*
3. Indefinite, *la, lo, le, li.*

Compounds with other particles—

1. Pointing near, *ro-ne, ku-ri, ke-li.*
2. Pointing far, *ka-la, nia-la, ku-ra, re-k.*

The languages in which these forms occur extend from the Loyalty Islands to the Solomons. In New Guinea and the Malay Region *la* is not apparent as a demonstrative, but is probably found in the Malagasy *iry*, that afar, *ary*, there.]

§ 7. Prepositions.

The prepositions of Hawaii and Ponape have much in common, though in form they widely differ.

The Hawaiian are: *a, o, ka, ko, na, no, i, ma, me, mai.*

The Ponape are: *en, ony, ni, iang, ki, pa, pan, ren, jong.*

The Hawaiian Grammar refers to two classes of these particles, the "simple" and the "compound." The "compounds" are the simple prepositions joined to other words, generally denoting place, and they may be regarded as "adverbs of place." The Ponape also possesses compound forms, but in these the simple prepositions suffix pronouns rather than adverbs, and they may be called pronominal prepositions rather than adverbs of place.

The "simple prepositions" possess in both tongues the mere office of "showing a connection and relation between other words."

There are three features to be especially noted as common to the two languages.

1. The simple prepositions are used to decline the noun and pronoun. The Hawaiian noun is spoken of as declined, but it is not declined in the proper sense of the term, *i.e.*, by possessing terminals to denote its relation to other parts of speech, as in Greek, Latin or German. There is nothing of this. But these simple prepositions come in, or some of them, to denote the relation of the noun, whether in the genitive, or dative, or other cases. As these are well marked by the preposition, the noun is spoken of as declined, an expression proper enough if it be understood. It has not been usual to speak of the Ponape noun as thus declined. It has been described as possessing the three general divisions, nominative, possessive, objective, but the last case was made to include the dative, accusative and ablative. This form of expressing the noun or pronoun arose from the fact that it is

very generally found with a possessive particle suffixed or prefixed. It is not in this respect, altogether like the Hawaiian free, or largely so.

In the Ponape almost every noun takes, as we have said, its possessive. But with these attached particles the preposition enters to play its part, and gives the cases —the Hawaiian noun possesses, the Genitive taking *en*, of, the Dative *ong*, to or for, the Accusative *ong*, to, the Ablative *ki* or *pan*, meaning by, and further taking *iang*, *ren*, denoting with.

If then the Ponape noun is arranged with the prepositions as in Hawaiian, we shall have it much the same. And this, it will be seen is not a mere form, but because the conditions as truly make for it as those affecting the Hawaiian noun.

2. The second point to notice with regard to the simple prepositions or some of them is, that they possess the power of marking a shade of difference among persons or things, a difference which the native mind is ever disposed to make. The objects of nature, persons and things, animate and inanimate, are often the subject of the narrowest distinctions. The Ponape mind has gone still further and made sharp distinctions in articles to be enumerated, and appointed *class* particles to designate them.[1]

In the Hawaiian the two prepositions *a* and *o*, while performing their prepositional office, take a further duty, *a* will denote one class of object, *o* another. As the grammar puts it "whatever relates to instruction, learning, work, food (and it may be added, children) requires *a*; whatever relates to one's own passions, person, residence, clothing, takes *o*."[2]

Passing to the Ponape noun we find the same method of marking the shades of difference, but different articles will be included.

---

[1] This use of classificatory particles is found also in Melanesian languages. *Cf.* Codrington, Mel. Lang. pp. 242, 305. In New Guinea also the numerals are preceded by words showing the kind of thing counted.

[2] Though called prepositions by Mr. Doane, these words may be shown to be really nouns. *Cf.* Codrington, Mel. Lang. p. 132. They are the only nouns which, in the Polynesian languages have retained the possessive suffixes.

What the Hawaiian would put into one category the Ponapean would put into another. This will be discussed further on.

3. The third point is the distinction inherent in the Hawaiian prepositions *ka* and *ko*. Their office is to express the possessive case, or that case expressed by the apostrophic *'s* in English, *ko ka hale*, the house's or that which belongs to the house, *ko ke kino*, the body's, or that which belongs to the body.[1]

The Ponape impresses much the same law on the particle *en*, using one particle rather than two. The first office of *en* is simply prepositional, to denote the relation expressed by the preposition of. But it has a larger use, to give forms or turns to the genitive, similar to the *ka* and *ko* of the Hawaiian. It does not as distinctly denote the form of the apostrophic *'s*, but it does give another meaning to the simple possessive. This will be more distinctly seen in the examples of declension.

The singular noun with the prepositions will sufficiently illustrate the points under discussion.

Hawaiian—KA HALE, the house.

Nom.	*ka hale,*		the house.
Gen.	*o ka hale,*	*a ka hale,*	of the house.
	ko ka hale,	*ka ka hale,*	the house's.
Dat.	*no ka hale,*	*na ka hale,*	for the house.
Acc.	*i ka hale,*		the house.
	ma ka hale,		at or to the house.
Voc.	*e ka hale,*		o the house.
Abl.	*mai ka hale,*		from the house.
	me ka hale,		with the house.
	e ka hale,		by the house.

Ponape—OL, man.

Nom.—Nom. *ol,*		man.
Poss.	Gen. *ol en,*	man of.
	Gen. *en ol, na, a,*	of the man.
Obj.	Dat. *ong ol,*	for the man.
	Acc. *ong ol, ni ol,*	to or at the man.
	Voc. *ol la,*	man o.
	Abl. *ren ol, iang ol,*	with the man.
	Abl. *pan ol, ki ol, jong ol,*	of or from the man.

[1] *Ka* and *ko* are abbreviations of *ka a*, *ke a*, or *ka o*, *ke o*, *i.e.* the article with the possessive words *a* and *o*.

Looking at the Hawaiian noun as thus declined we see how completely this is done by the prepositions, and notice that the Ponape noun may be declined in the same way. We observe the force of the preposition *en*, and its twofold use. The first simply denotes of, as man of, while the second use, of the man; or the man's denotes that which more particularly pertains to, or belongs to the man. Here we get much that is analogous to the Hawaiian *ka*, *ko*, yet as we have remarked, it does not denote simply and solely the apostrophic *'s*. It may do so, but the idea is rather to give a new form to the genitive. At times it seems to be required by the peculiar state of the noun with its suffix or prefix, and sometimes seems to be demanded to satisfy the ceremonial form of address. But we need not remark further, the two forms exist and hold much that is analogous to the Hawaiian *ka* and *ko*.

Then as to that other very peculiar and marked characteristic of the two tongues, to denote "the shade of difference between things" in the Ponape the law is as marked as in the Hawaiian, but in the Ponape it is expressed by the two particles *na*, *a*, *personal pronouns*, rather than prepositions.[1] *Na* equals *a* in Hawaiian covering the possessive of certain things, while *a* in Ponape also indicates the possessive and resembles in its shade distinction the *o* of Hawaiian. These words will be further referred to under pronouns.

§ 8. Nouns.

We cannot better present these than by following somewhat closely the order of the Hawaiian Grammar.

1. The Hawaiian noun takes both the abstract and the concrete state, so also does the Ponape, though in the latter the abstract is the more common.

[1] Since these words correspond to what Dr. Codrington has called Possessives (Mel. Lang. p. 128), and are used in Ponape with suffixed pronouns, like nouns denoting relationships and parts of the body, *e.g.*, *nai*, *nom*, *na*, etc., *ai*, *am*, *a*, etc., it would be more correct to call them possessive nouns. *A* is of general use; *na* is used of kava, sugar cane, banana, dog, child, fowl and is of more limited application.

Examples.	Hawaiian.	Ponape.
Abstract	*ka oiaio*, the truth	*pirap*, theft
	ka pono, the justice	*lamalam*, purpose
	ke kaumaha, the weight	*likak*, grief
	ka ino, the badness	*toto*, weight
Concrete	*elemakule*, an old man	*kirip*, unmarried person
	luwahine, an old woman	*peneinei*, a married couple
	halau, a long house	*tanipaj*, a chief's house
	oopa, a lame person	*pokolong*, a cripple.

2. The Hawaiian noun is often formed by prefixing a syllable to the "radical form." The syllables so used are, *ma*, *na*, *po*, *ko*, *o*, thus :—

malu, shade, *mamalu*, umbrella

hae, to break, *nahaehae*, rent, broken

ino, bad, *poino*, unfortunate.[1]

Ponape observes the same rule but with different particles:

pirap, to steal, *li-pirap*, a theif.

patak, to teach, *joun patak*, a teacher.[2]

porone, to send, *wan-poron*, a messenger.

The Ponape particles most generally used are *li*, *jou*, *wan*, *ai*, *ka*, *kan*.

3. In Hawaiian person, number, gender, and case are not indicated by any change in the noun itself. The same applies to Ponape.

4. The singular, dual and plural numbers are distinguished in both languages, but there is no change in the noun itself, particles of peculiar form being used.

5. The signs of the Hawaiian dual and plural are, (excluding numerals) *na*, *mau*, *poe*, *pae*, *puu*.

---

[1] Examples of this formation are not very clear in the Hawaiian Grammar. The words given are verbs rather than nouns.

[2] The word *jou* is the Melanesian *ta* or *tau*, man. *Cf. jou n patak*, man of teaching, with the New Guinea Motu, *ahediba tauna*, teaching its man.

In Ponape the particles are, *a*, *ka an* (or *ke en*), *kan*, *kat*, *ka*, *ko*.[1]

Hawaiian *na* denotes indefinitely large numbers, *poe* is a sign of plurality as indefinite, but is restricted to the set or company of things under discussion, and is used more in reference to persons and animals than to inanimate objects. *Pae* and *puu* have much the same office of plurality as *poe*, but refer rather to collections of things inanimate.

In Ponape, *kaan* (or *keen*) gives plurality, but with the special idea of "repetition," "rows." *Kan* denotes plurality, any number above duality. *Kat* refers to numbers equally as large, but they must be things "at hand" in close proximity; the particle does not notice the kind of thing, whether animate or inanimate. *Ka* is much the same as *kat*, but refers to objects or persons at a little further remove. *Ko* still expresses plurality large or small, above the dual, but has no reference to persons, or things distant in time or place.[2]

Tabulated the particles would stand thus:—

HAWAIIAN.

Na, plurality indefinitely large.
Pae, plurality of objects under discussion and objects inanimate.
Puu, nearly the same as *pae*.
Poe, plurality, relating to things under discussion, excluding all others, refers to animate objects.

PONAPE.

Kaan (or *keen*), plurality, but things in rows; repetition.
Kan, plurality, all above duality.
Kat, plurality, but only of things at hand.

---

[1] In Gulick's Ponape Grammar *ka* seems to be used as a noun of multitude. *Ka'n im* a multitude or collection of houses, (*Cf.* Fiji *rei valu*) a village. *Kan* is not referred to separately, but is given as a demonstrative, all these or those. *Ko* is given as a pronoun and referred to a demonstrative *kao*.

[2] In Mortlock Island *kana* is the usual sign of the plural. In Ebon, Marshall Island, *ko* is used for the plural, except with names of human beings.

Ka, plurality of things under discussion but a little more removed.
Ko, plurality of things under discussion, far removed, but animate or inanimate.

The Hawaiian Grammar gives all the above particles as also signs of the dual, adding to them the *mau*, as an expression to denote a few.

The table shows how each language is governed by a common law in expressing the dual or plural by particles.

6. *Gender.*—"There is nothing in Hawaiian to mark the genders of nouns." The real difference, existing in animate beings is denoted by words expressive of sex. This is denoted by the words *kane*, male, *wahine*, female.[1] The same rule applies to the Ponape, the words used being *ol*, male, and *li*, female. In both languages different words are use to designate the gender, as the words for parents, children, animals or fowls.

§ 9. Adjectives.

There is much similarity in the use of the adjective.

1. The Adjective of Quality.

Hawaiian—*He manawa loihi*, a long time.

He papa makolukolu,[2] a thick board.

Ponape—*Anjou uarai*, a long time.

Par en tuka mejul,[2] a thick board.

2. Adjective of Quantity.

Hawaiian—*He makani oluolu*, a pleasant breeze.

Ka la ino, the stormy day.

Ponape—*Ang tik*, a light breeze.

Ran katauin, a rainy day.

---

1 Sam. *tane, fafine*, etc.

2 These words *makolukolu*, and *mejul* are representatives of a more common *matolu*. *Cf.* Samoan *matolutolu*, thick (pork), Maori, *matotoru*, Efate *matulu*, Malekula, *metetir*, Epi, *mererolu*, Mota, *matoltol*. All of these words have the conditional prefix *ma*. *Cf.* also the Fiji *tolo*, the thick part of the body or of a tree.

3. The Adjective of Number.

Hawaiian—*Lehulehu na kanaka*, numerous people.
Na kanaka umi, the ten men.

Ponape—*Aramaj ngeter*, many persons.
Ol rick, twenty men.

The general law of the adjective of both tongues is, that it shall follow the noun qualified. It is exceptional when it does not.

In Hawaiian the numeral is allowed to precede the noun. This is at times the case in the Ponape, though usually the numeral follows the noun, thus :—

Hawaiian—*Eha hale kula*, four school houses.
Elima la papa ka oleo ana, five days perhaps the discussion lasted.

Ponape—*Ran limau*, five days.
Im patak uonu, six school houses.

4. In both languages a particle prefixed to an adjective becomes its copula,[1] to express or affirm the quality of the adjective. In Hawaiian the particles are *wa*, *he*, thus :

wa ino, it is bad ; *wa maikai*, it is good.
he ino, it is bad ; *wa loiho ke ala*, long is the road.

In the Ponape this equally marked, but only one particle is used, thus :—

me juit, it is bad ; *me mau*, it is good.
me rai rai, it is long ; *me tikitik*, it is small.[2]

---

[1] In these we probably have the remains of former verbal particles. *Cf. wa* with Banks Island *we*.—Mel. Lang. p. 276.

[2] Gulick (Amer. Orient. Soc. Journ., Vol. x., p. 30) regards this *me* as the same as the Polynesian *mea*, thing, substance, any person or thing mentioned ; *me mau*, thing good, or the thing (or it) is beautiful. There seems, however, very little doubt but that it is the particle *ma* or *me*, which is almost universally used in Melanesia to express the *condition* in which a thing is.—(Mel. Lang. p. 169, 188). It seems possible so to regard it in Ponape. Gulick states "It very commonly takes the power of a personal pronoun and stands in apposition with the nominative of a verb, so heightening the affirmative force of a sentence, and almost entitling it to the term "affirmative particle." *e.g.*, *kowa me wiata*, you are the one that did (it). *Ape me koto*, such a one has come. In this affirmative use, we may compare *me* with the *m*, *me* or *ma* so common in Melanesia as a verbal sign.

5. *Comparison of Adjectives.*—The three degrees, positive, comparative, and superlative, common to all languages are here expressed much in the same way, though by different agents.

Particles are used in both languages to form these degrees, the two latter especially.

In Hawaiian the positive degree is the simple expressed subject, long, short, white, black. There is nothing in the adjective to express comparison, thus :

Hawaiian Positive, *poko*, short
Comparative, *poko iki*, short a little
poko ae, shorter (*lit.* short really)[1]
poko iki ae, shorter still.
Superlative, *poko loa*, shortest, very short.[2]

In Ponape the order is somewhat different, especially in the comparative. The positive simply asserts the long or short, the good or bad, the black or white condition of things under discussion. The comparative appropriates the preposition *jong*, from to express its comparison, as, this is white from, or whiter than that.[3] The comparative as in Hawaiian is often expressed by simply stating that one thing is different from another, as, this is long, that is short ; this is good, that is bad. The superlative is formed by suffixing the particle *ia*, and by taking a heavy accent.

Ponape Positive, *mau*, good.
Comparative, *mau jong*, better than (*lit.* good from)
puot jong, whiter than (*lit.* white from)
Superlative, *mau ia*, best of all, supremely good.
puotopuot ia, whitest of all.

---

[1] *Ae* in Marquesan augments the force of the word to which it is added and forms a comparative.

[2] *Loa*, really means long (of time and measure), here it means very or excessive.

[3] This is the common Melanesian Method. *Cf.* Ex. in Codrington's Mel. Lang. Mota, *o qoe we poa ran o gasuve* ; Maewo, New Hebrides, *a qoe u lata dan na gariri* ; Wango, Solomon Islands, *bo raha bania kasuve*, a pig is big from a rat; New Britain, *ingalo tadiat*, it is large from them.

[Mr. Doane has not discussed the use of *maj* in Ponape with the superlative. This word intensifies the quality or number expressed by the adjective, *maj totoia*, very numerous indeed, *majapueka*, exceeding afraid. It is the same as the Duke of York Islands and New Britain, *mat* and the Florida, Solomon Island *mata*, and in these languages it is used as an intensive in the same way. Duke of York *liralira mat*, very white, New Britain *I quqn mat*, he rejoices very much. The word is probably the common Oceanic *mata*, eye, face, front, also used as an adverb, before.]

Part II.

§ 10. Numerals.

The numerals are distinguished in both Ponape and Hawaii as cardinal and ordinal. Hawaii also possesses distributive forms. The first ten numbers stand thus:

	Cardinal.		Ordinal.
Hawaii.	*Ponape.*	*Hawaii.*	*Ponape.*
1. kahi	at	ka mua	ka at[1]
2. lua	ari	ka lua	ka ari
3. kolu	ejil	ka kolu	ka ejil
4. ha	apong	ka ha	ka apong
5. lima	alim	ka lima	ka alim
6. ono	auon	ka ono	ka auon
7. hiku	ej	ka hiku	ka ej
8. walu	aual	ka walu	ka aual
9. iwa	atu	ka iwa	ka atu
10. umi	katongaul	ka umi	ka tongaul

In the formation of the ordinal, particles come into use which are alike in form and office. In the Hawaiian it is the definite article *ka*, in the Ponape the causative. In what we may call the infancy of things, both were no doubt one, but in the lapse of ages and wide roaming of the people from the home land they became possessed of different powers. One people has taken *ka*

[1] This ordinal is often *ka moa*, the first, before all others, the first in precedence.—Rev. E.T.D.

for the definite article, the other has appropriated to it, the office of a causative.

[The names of the numbers in these decimal systems are substantially the same in both languages, but the Ponape words for four and nine, *apong* and *atu* are uncommon. These agree with the Palau Islands *uwang*, *oang*, four, and *etteu*, *eteu*, nine, which are probably only forms of the common *ua*, *fa*, and *sio*, *siwa*.

The Hawaiian *kahi* by a regular change of *t* to *k*, and *s* to *h*, is the common Polynesian *tasi*, which, though probably formed from the root *ta* or *sa*, common in Melanesia does not agree with it so closely as the Ponape *at*. The change of *t* to *k*, and *f* to *h* in Hawaiian, and of *t* to *j* in Ponape show *kolu* and *ejil*, *hiku* and *ej* to be the common *tolu* and *fitu*.

The ordinals in Hawaiian appear to follow the ordinary Polynesian rule and prefix the article as in Maori, *te tahi*, *te rua*, *te toru*, Samoan *'o le lua*, *'o le tolu*. The Ponape *ka* prefixed though identical in form with the causative prefix may not be really the same. In Fiji and other Melanesian languages, and also in Malay, the ordinal is formed by a prefix *ka* or *ke*, *e.g.*, Fiji *karua* second, Efate and Nguna *kerua* second, *kelima* fifth, Malay *kaduwa* second. In these languages *ka* is not the causative prefix and hence the Ponape *ka* (and possibly the Hawaiian) may be of similar origin to the Fiji *ka*. In Melanesia the causative prefix usually forms a multiplicative numeral as in Banks' Islands *raga-rua*, twice, *raga-tol*, thrice. This form is also found as ordinal in some parts of Melanesia, but usually with a substantive termination. In Malagasy also the causative *faha* forms an ordinal *faha-roa*, second. The Ponape ordinal *ka moa* shows the word *moa* or *mua*, used in many languages of Oceania for "front," "before." Banks' Islands *moai*, first.]

The Hawaiian Grammar notes that "Formerly, in counting, the Hawaiians, when they reached the number forty turned back and commenced at one and counted another forty, and so on till they laid aside ten forties; these ten forties they called a *lau*,

four hundred. It is a modern improvement that the word *kana* has been prefixed to *lima*, *ono*, *hiku* etc. to express fifty, sixty, seventy, etc. At the present time the Hawaiian enumerate by units, tens, hundreds, thousands. The words *haure*, hundred, *tausani*, thousand, *miliona*, million, have been introduced from the English.

The order of counting by fours was as follows:

aha kahi	= four units	= 1 *kauna*	=	4
umi kauna	= ten fours	= 1 *kanaha*	=	40
umi kanaha	= ten forties	= 1 *lau*	=	400
umi lau	= ten 400s	= 1 *mano*	=	4000
umi mano	= ten 4000s	= 1 *kini*	=	40000
umi kini	= ten 40000s	= 1 *lehu*	=	400000[1]

Turning now to the Ponape we find the same method of fours in use. It is less perfect than the Hawaiian, but though simpler was probably derived from a common system. The terms are as follows:

Four units are termed	*at*	= 1
Another ,, ,, ,, ,,	*ari*	= 2
,, ,, ,, ,, ,,	*ejil*	= 3
,, ,, ,, ,, ,,	*apong*	= 4
,, ,, ,, ,, ,,	*alim*	= 5

This order is followed till the tenth number is reached which is called forty. This order repeated gives 40 + 40 = 80, this repeated again = 80 + 40, *i.e.*, 120 and so on *ad infinitum*.

The Ponape system is the simpler of the two, but it seems quite impossible that two peoples should have such a system unless they held much in common to both.

[1] These words have various meanings in the other Polynesian dialects. *Kauna* may be the same as the Tongan and Maori *te kau*, ten pairs. *Kana-ha* is simply 'ten fours.' *Lau* is 100 in Samoan, and is the Tongan *au*, Rarotongan *rau*, also meaning 100. *Mano* is 1000 in Maori, 2000 in Rarotongan and Tahitian, 10000 in Samoan, Tongan, and 1000 in Hawaiian and Marquesan. The Hawaiian *kini*, Marquesan *tini* is 40000, but Maori *tini* is 10000, and Rarotongan 20000, and an indefinitely large number in Mangarevan. Hawaiian *lehu* is Tahitian *rehu*, 200000, Fiji *levu*, great.

§ 11. Pronouns.

The personal pronouns in these tongues are:

Hawaiian.		Ponapean.	
Singular.		**Singular.**	
au, wau	I	*ngai, ī*	I
oe	you	*koe (komui*, chief's lang.)	you
ia	he, she, it	*ī, a*	he, she, it
Dual.		**Dual.**	
maua (exclusive)	We two	*kita* (exclusive)	We two
kaua (inclusive)	We two	*kit* (inclusive)	We two
olua	you two	*koma*	you two
laua	they two	*ira*	they two
Plural.		**Plural.**	
makou (exclusive)	We	*kit, je*	we
kakou	we	*kitail*	we
oukou	you	*komail*	you
lakou	they	*irail*	they

In the second personal pronoun the Hawaiian *oe* is Ponape *koe*. In the third person *ia* is bisected in Ponape but intact in Hawaii. Both tongues have forms in the dual and plural to express the inclusion or exclusion of the person addressed. All wear a strong family look.

[The Hawaiian pronouns are substantially the same as in other Polynesian languages. In the dual first and third persons *ua* is an abbreviation of the numeral *lua*, two. Similarly in the plural *kou*, is an abbreviation of *kolu*, three, the common *tolu*.

The Ponape presents some differences which are worth noting. *Ngai* is a Melanesian rather than a Polynesian form. In the dual and plural *ki, i*, may be regarded as demonstratives, and are used similarly in many Melanesian languages.[1] In the plural *il* is an abbreviation of *ejil*, three.[2] The root forms compared in the two languages are thus

[1] *Cf.* also the Tongan *kimaua, kitaua*, etc., Aniwa *agimaua, ajitaua*.

[2] *Cf.* similar abbreviations in the Solomon Islands Languages.—Codrington, Mel. Lang. p. 507, 512, etc.

Singular, Hawaiian 1 *au*, 2 *oe*, 3 *ia* Plural Hawaiian 1 *mā*, *ta*, 2 *o*, 3 *la*

Ponape *ī*, *koe*, *i*. Ponape *t*, *ta*, *om*, *ra*.]

With the prepositions the first personal pronouns are as follows:

Hawaiian.			Ponape.		
Nom.	*au, wau*	I	Nom.	*Ngai, ī*	I
Gen.	*o'u, a'u*	of me	Poss. Gen.	*nai, ai*	mine
Gen.	*ko'u, ka'u*	mine [to me	Poss. Gen.	*en nai, en ai*	of mine
Dat.	*no'u, na'u*	for me, belonging	Dat	*ong in*	for me
Acc.	*ia'u*	me, to me [of me	Dat.	*ong, nai, ai*	for mine
Acc.	*na o'u la*	by me, by means	Acc.	*ongin*	to me
Abl.	*mai o'u la*	from me	Abl.	*rei*	with me
Abl.	*me au*	with me, like me	Abl.	*pai*	by me as agent.
Abl.	*e au*	by me as agent			

The chief features in the plural and dual are the distinction between the exclusive and inclusive in the first person, but there is no need to give here the full forms. The point to notice in the declension of the pronoun is the distinction made in the use of the genitive singular, and the agreement of the two languages. The Ponape *nai* and *ai* of the first person, *nom* and *am* of the second, *na* and *a* of the third, agree with the double forms of the Hawaiian *o'u, a'u*, for first person, *ou, au* of the second, *ona, ana* of the third. The use of these may be sufficiently illustrated by the Ponape *nai* and *ai* for the first person singular genitive. These words are both suffix and prefix, at least *ai* is emphatically so, thus *nar ai*, canoe my, or *ai nar*, my canoe; so also *ai im*, my house, *im ai*, my house. The *nai* is more generally a prefix. It is doubtful if it ever becomes a suffix, if so, only in a special sense. As possessive pronouns both are important, and it is in this pronominal form that they carry the character of the Hawaiian prepositions *a* and *o*, and indicate the "shade of difference between things" which has been already spoken of (§ 7 Prepositions).

The Ponape *a* is the equivalent of the Hawaiian *o*, and stands as the exponent of all possessions, goods, lands, boats, canoes, largely things with which to work, then relations, the brother,

sister, uncle, aunt, parents, and wife. Ponape *nai* is the *a* of Hawaii, and possesses a narrower range of service. It refers to children, to servants, to trees and their fruits, to certain implements of work, and also to things which are highly prized. The two pronouns stand thus in wide contrast, and may be thus illustrated: In what may be called the "stone and shell age" of this people, the possession of a piece of iron hoop was of more worth than its weight in gold; and one getting possession of a knife, that was a treasure indeed, at once addressed it as *nai kapit*, my knife, but his wife at his side, a piece of property he could pick up at any time or anywhere was addressed as *ai pant*, my wife.

We need not further illustrate this point, we only refer to it to show how fully this idea of the different shade of things has possessed the Ponape mind. It is as strong with him as with the Hawaiian. But while the Hawaiian lets the preposition bear the the office of expressing the "shade of difference," the Ponapean has passed it on to the personal pronoun.

We may perhaps say here all that is needed to be said on the prefixed pronoun of the Hawaiian. It is simply the inferior brought to the front, made to face about and take a new position: *he aina o'u*, the land of mine; *he kapa o'u*, the cloth of mine become *ko'u aina*, my land; *ko'u kapa*, my cloth.

Now as we have intimated above in the remarks on *nai* and *ai*, Ponape possesses the same order, sometimes a prefix, sometimes a suffix. But the change cannot be so fully made as in the Hawaiian, for certain articles are restricted to either the suffix or prefix, but apart from this the idea is the same.

[The distinction made between nouns when used with the possessive pronoun, or rather the difference made in the pronoun when used with certain nouns, though obscure in the Ponape and Hawaiian may be clearly understood by reference to the Melanesian languages. In these certain nouns are used with a pronoun suffixed, others require a particular form of possessive word to be used with them, and the latter can always be shown to consist of

another noun with a suffixed pronoun. Thus taking examples from Mota of Banks' Islands and from Fiji, we have :

1. Mota *-k*, Fiji *ngga*, used as suffixed pronouns to names of parts of the body and relationships : *qatu-k*, *ulu-ngga*, my head, *tama-k*, *tama-ngga*, my father. The Ponape suffixed pronoun is also used with the same kind of nouns: *mong-ai*, my head, *jam-ai*, my father. So also other Micronesian languages: Gilbert Islands *atu-ku*, *tama-ku*, Marshall Islands *bor-a*, *jem-a*. No examples of this construction are found in the Polynesian languages.

2. In Mota 'my garment' is *no-k siopa*, Fiji, *no-ngga isulu*, where *no* is plainly a noun used with the same pronouns suffixed as in the previous examples. If *no* be translated "thing" or "property," the literal construction is my thing (a) garment, and the Ponape *nai (na-ai) kapit*, my knife is of the same form. The Hawaiian *koʻu kapa*, my garment is in Maori *toku kahaka*, and in these the *ʻu* and *ku* are suffixed pronouns, being in fact of identical origin with the Mota, Fiji and Gilbert Island forms given above. The Hawaiian *k*, and Maori *t* represent the articles *ke* and *te*. Hence the *o* in Maori and Hawaiian may be regarded as of the same use as the Mota and Fiji *no* or the Ponape *na*. The construction is identical in the Melanesian, Micronesian and Polynesian tongues.

3. It is probable that the Ponape prefix possessive *ai* is distinct from the suffix *ai*, and that the pronoun is really *i*. *Cf.* the prepositions *rei*, with me, *ren*, with him, *pai*, with me, *pan*, with him.

§ 12. Verbs.

1. The Hawaiian verb as shown in the grammar is certainly elaborate when compared with that of Ponape. Possessing about as many moods, the tenses are more numerous and fuller, so are the causative forms. The passive voice is more perfect. Whether we may call it "philosophical for a language to agglutinate to itself so many particles to explain the various shades of thought needing to be expressed, when the same particles in their tense

use often exchange themselves one for the other, may be questionable." But for the "philosophy of things we are not seeking." As a first remark upon the verb we may say, in almost the opening sentence of the Author of the Hawaiian Grammar, "in comparison with European languages the Hawaiian verb has many peculiarities. In every full sentence of these languages a verb is necessary to complete the idea intended. No so in Hawaiian; some of the most common, clear, and strong affirmatives are fully expressed without any verb." This feature is also characteristic of the Ponape verb.

2. We will here group as far as we can all that is said in a preliminary way of the verb.

(1) The grammar states: In Hawaiian a verb is not necessary to complete the idea. This, as stated above is true also of the Ponape sentence.

(2) In Hawaiian there is no verb to express the idea of existence or being. This is expressed by particles, and by the pronoun in the nominative or objective cases. Ponape has the same use.

(3) There are no verbs in Hawaiian (and also in Ponape) to affirm the quality of a substance, this being done by adjectives, nouns or pronouns.

(4) The verbs 'to possess,' 'to have,' in the Hawaiian are wanting, equally so in Ponape.

(5) The verbs to express duty or obligation are wanting in Hawaiian and also in Ponape.

(6) There are no variations of the Hawaiian verb to express number or person, neither are there any in the Ponape. In both languages the pronoun expresses these, and more distinctly than the noun.

3. We here reach what may be called the "accidents of the verb," and will now give the verb as affected by these. In the three numbers, singular, dual, and plural, the paradigm is as follows:—

	Hawaiian.	Ponape.
	Hele, go.	*Tang*, run.
	Singular.	Singular.
1st Person	*hele au*, I went	*ngai tang*, I ran
2nd Person	*hele oe*, You went	*koe tang*, You ran
3rd Person	*hele ia*, He went	*a tang*, he ran
	Dual.	
1st Pers. (excl.)	*hele maua*, we two went	*kit tang*, we two ran
1st Pers. (incl.)	*hele kaua*, we two went	*kita tang*, we two ran
2nd Person	*hele olua*, you two went	*koma tang*, you two ran
3rd Person	*hele laua*, they two went	*ira tang*, they two ran
	Plural.	
1st Pers. (excl.)	*hele makou*, we went	*kit tang*, we ran
1st Pers. (incl.)	*hele kakou*, we went	*kitail tang*, we ran
2nd Person	*hele oukou*, you went	*komail tang*, you ran
3rd Person	*hele lakou*, they went	*irail tang*, they ran.

In this table we have the verb, simple, fixed and unvaried. In the Hawaiian it is simply *hele*, to go, in Ponape, *tang*, to run. There is not the least change in the verb, but person and number are entirely indicated by the pronoun.

4. *Moods*—In the Hawaiian there are four moods, Ponape possesses five, thus:

Hawaiian—Indicative, subjunctive, infinitive, imperative.

Ponape--Indicative, potential, subjunctive, infinitive, imperative.

5. *Tense*—It is the same with tense as with person and number, there is no alteration of the verb which expresses this. Particles must come in, and it may be remarked generally, that when particles are appointed to express the tense of the verb, there is not a little uncertainty about the whole matter. However as in both tongues the particles of time are used, they answer their purpose very well.

6. The Hawaiian Grammar begins with the preterite tense, and we follow the same order. There are five forms of this tense in Hawaiian, but only three in Ponape. In illustrating this point we will give the three Hawaiian corresponding to those of Ponape, in the singular of each form.

Hawaiian.	Ponape.
First form of the preterite. The simple form of the verb.	First form of the preterite. Simple form of the verb.
1. *holo au*, I ran	1. *I tang*, I ran
2. *holo oe*, you ran	2. *ko tang*, you ran
3. *holo ia*, he ran	3. *a tang*, he ran.
Second form; this form prefixes *a* to the verb, meaning "and when," thus:—	Second form; this form prefixes *ap*, meaning "and then" or better, "then" simply.
1. *a hana au*, and when I made	1. *I ap uia*, I then made
2. *a hana oe*, and when you made	2. *ko ap uia*, you then made
3. *a hana ia*, and when he made	3. *a ap uia*, he then made
Fourth form; the verb prefixes *ua*.[1] This particle according to the grammar is more often used as the perfect tense.	Third form; this form uses the particle *er* suffixed, and denotes "done, perfected, finished."
1. *ua huna au*, I have concealed	1. *I ua er*, I have brought
2. *ua huna oe*, you have concealed	2. *ko ua er*, you have brought
3. *ua huna ia*, he has concealed	3. *a ua er*, he has brought

7. *Future Tense*—The Hawaiian possesses two forms of this tense. The first prefixes *e* to the root,[2] the second has an additional *e* suffixed, thus:—

First Form.	Second Form.
1. *e lohe au*, I will hear	1. *e lohe e au*, I shall have heard
2. *e lohe oe*, you will hear	2. *e lohe e oe*, you will have heard
3. *e lohe ia*, he will hear	3. *e lohe e ia*, he will have heard

Ponape also possesses two forms of this tense. The first is denoted by the particle *pan*,[3] "will," prefixed, the second by the particle *nok*, meaning "shall, intend," or "about to."

First Form.	Second Form.
1. *I pan rong*, I will hear	1. *I nok uia*, I shall or intend to do

[1] This is the common *kua* of Polynesia, usually a perfect sign.

[2] In Samoan, Maori, Tongan and Marquesan, *e* is both a present and future particle. In Rarotongan and Tahitian it is usually future, but sometimes present.

[3] *Pan* is a verb common in Melanesia as *van, vano*, to go. Hence Ponape *pan rong* means "going to hear." *Cf.* Lifu *tro deng*, also meaning "going to hear."

2. *ko pan rong*, you will hear	2. *ko nok nia*, you will or intend to do
3. *a pan rong*, he will hear	3. *a nok nia*, he will or intends to do

8. *Present Tense*—The present tense of the Hawaiian verb differs so materially from the Ponape, that both are here omitted.

9. *Subjunctive Mood*—Particles are used to indicate this mood in both languages, but the simpler use is found in Ponape.

10. *Imperative Mood*—The Hawaiian grammar shows two forms of this mood, both indicated by particles. The first prefixes *e* to the verb, thus: *e nana oe*, look you. The second form prefixes *mai*, "do not," to the verb, thus: *mai huli oe*, do not you turn. The Ponape also possesses two forms, the first prefixing *en*, the second *ter*: *e.g.*, *en ngar*, do you look, or simply, look: *ter tang*, do not run.

11. *Infinitive Mood*—In the Hawaiian, the grammar notes that this mood is not infrequently of the same form as the imperative, and can only be distinguished by the sense of the passage. This is also true of the Ponape verb. In Hawaiian, however, the particle *e* is prefixed to the root of the verb to indicate the "to" of the English infinitive.

§ 13. Participles.

1 These are marked in the Hawaiian. Certain particles are used to designate them, called the present and preterite, *e.g.*, *e lawe ana*, carrying; *i lawe ia*, carried. The same idea is not indicated in Ponape by a particle, but usually, the simple form of the verb is used participially. The reduplicated form of the verb gives a present participle, *tang*, to run, *tangtang*, running: *alu*, to walk, *alualu*, walking.

The Hawaiian has a *Gerund*. "It takes the definite article *(ka)* or a prefix pronoun"; *ka lawe*, the bearing, *ka papa*, the forbidding. Ponape possesses a part of speech similar to this, or it may be called a verbal noun. It prefixes, *ka* causative, and suffixes a prepositional pronoun, thus: *ka maua pa-i*, "the making good of me."

2. *Other Verbal expressions*—(*a*) The Hawaiian possesses a passive voice, formed by suffixing *ia* to the root of the verb. Ponape also possesses a passive, which exists in two forms. The first, and more regular, prefixes the preposition *pa* to the root. The other form is made by suffixing certain particles to the root.

(*b*) The Hawaiian verb is reduplicated in the following ways:

(1) First syllable only: *lawe*, to carry, *lalawe*.

(2) Both syllables; *lawelawe*.

(3) Second syllable only: *lawewe*.

(4) First syllable is repeated three times: *lalalawe*. This gives a frequentative sense, "to carry often."

The Ponape possesses some of these forms.

(1) The simple root is reduplicated: *tang*, to run, *tangtang*.

(2) First syllable only: *naitik*, to beget; *nainaitik*.

(3) The root except the last letter: *matang*, to play, *mata-matang*.

(4) A syllable is inserted, similar in sound: *inta*, to say, *in(tin)ta*.

The reduplicated forms while somewhat numerous in Ponape, do not possess the power of the Hawaiian, to beget new forms of conjugation, nor is the meaning of the word so materially changed.

The Hawaiian possesses a causative form, made by prefixing the particle *hoo*: *hoo-lawe*, to cause to carry, *hoola*, to save, to make live. Ponape has also a causative, formed by prefixing *ka* to the verbal root, *ka-maur*, to make live, *ka-mela*, to kill, make dead.

[Though so dissimilar in form these two prefixes are probably of identical origin. Hawaii is exceptional among the Polynesian languages in having the form *hoo* for the causative. The prefix is the same as the Marquesan *haa*, which by the elision of *k* and substitution of *h* for *f* is the *faka* of Tonga.[1]

The prefix among the Melanesian languages takes similar variations. In Fiji it is *vaka*, in the New Hebrides, *vaka* or *vaga*.

[1] That the syllable *ho* is the representative of *fa* or *fe* is evident by comparing allied words in the Polynesian tongues: *e.g.*, words for land, star: Hawaiian *honua*, *hoku*; Tongan *fonua*, *fetuu*; Samoan *fanua*, *fetu*.

in the Solomon Islands it is *faga* or *haa*. A very common Melanesian form is *fa*, *va*, *wa* or *ha*, in the Loyalty Islands *a* or *o*. Coming to the Micronesian languages we find the same prefix. As in Melanesia it is simplified by the suppression of the guttural so in Micronesia it is usually wanting in the labial. Hence the Kusaie *ak*, Ponape *kuk*, Ebon and Gilbert Islands *ka*. This is further weakened in the Mortlock Islands to *a*.]

§ 14. Verbal Directives.

"Verbs generally, in Hawaiian, are supposed to have a motion or tendency in some direction. This motion or tendency is expressed by several little *words* which follow as near after the verb as the construction of the sentence will allow. The motion is either *towards* the speaker or agent, or *from* him, *up* or *down* or *sideways*, either to the right hand or left. Even those verbs expressive of the most quiescent state, have this peculiarity. We have something similar in the English phrases, *drink up*, *drink down*, etc." This paragraph from the Hawaiian Grammar applies also to Ponape.

Hawaiian Directives are:	Ponape Directives are:
Mai, hither, towards one	*To*, towards one
Aku, from the speaker	*We*, from one, a short distance
Iho, downwards	*La*, from one, at the farthest extreme
Ae, upwards	*Ta*, upwards
Ae, also means 'sideways' or oblique motion.	*Ti*, downwards.

[The Hawaiian directives are those common in Polynesia: *mai*, *atu*, *ifo*, *ake*. They are used also in most Melanesian languages, the two last in the fuller forms of *sivo* and *sake*. In Micronesia the Ponape directives seem to be limited to the Caroline Islands languages, Ebon has *tok*, hither, *lok*, thither. The Gilbert Islands have the Polynesian directives in the forms, *mai*, hither; *rio*, downwards, *rake*, upwards. The directive 'thither' is *nako*, which is commonly used as a verb 'go' in Melanesia. *Cf.* Fiji *lako*.]

The following table illustrates the use of the directives:

Hawaiian—*lawe au mai*, I brought hither
lawe au aku, I took away
lawe au iho, I took down
lawe au ae, I took up.

Ponape—*I ua to*, I brought here, to the speaker
I ua we, I carried from the speaker, a short distance
I ua la, I carried from the speaker, far off
I ua ti, I carried down
I ua ta, I brought up.

§ 15. Syntax.

Our remarks on this subject will be few, because in the main there is so much of unity. In the Hawaiian the subject is rarely the first member of a sentence—a verb may and *often* does take its place. On this point the divergency of the two tongues is marked. In Ponape the noun is usually the first member, and it is rare to see the verb in any other position than following its subject. In all the minor parts of speech, the adjective following the noun qualified, the adverb or directive its verb, the similarity in both tongues is striking.

[The Ponape order is that common in Melanesia, except in Fiji and a few other places. The Hawaiian is the usual Polynesian order.]

§ 16. Comparative Vocabulary.

[In comparing these lists it must be remembered that in common Oceanic words: *t* is represented by *j* in Ponape, by *k* in Hawaiian; a common *f* is dropped in Ponape, and is *h* in Hawaiian; a common *k* is retained in Ponape, but is dropped in Hawaiian; the common *ng* is retained in Ponape, but becomes *n* in Hawaiian.]

English.	Ponape.	Hawaiian.
Animal	*man*	*manu*, bird. Common
Bag	*et*	*eke*
Before	*moa*	*mua*. Common
Breadfruit	*mai*	*mei*

English.	Ponape.	Hawaiian.
By (prep.)	*ki*	*i*
Canoe	*uar*	*uaa*. Common *vaka*
Cold	*pau*	*hau*, cold breeze
Conjunction	*a*	*a*
Cocoanut tree	*ni*	*niu*. Common
Die	*mat*	*make*. Common *mate*
Face	*maja*	*maka*, eye or face. Common *mata*
Father	*jama*	*tama*, son. (*tama* expresses the relationship between father and son, rather than the persons.)
Fear	*majak*	*matau*
Fight	*pei*	*papai*, to strike
Fire	*ai, iai*	*ahi*
Fish	*man-ika*	*ia*
Five	*alim*	*lima*. Common
Fly, (insect)	*long*	*nano*. Common *lango*
Food, chewed	*mama*	*mama*, to chew
Fruit	*ua*	*hua*
Hand	*lim* (chief's lang.)	*lima*. Common
Hear	*rong*	*lono*. Common *rongo*
Mili, one of the Marshall Islands under which is the abode of the departed	*mili*	*milii*, god of the infernal regions
Moon	*marama*	*malama*. Root *lama*, shining.
Moss	*lim*	*limu*
Mouth	*au*	*auha*
Night	*pong*	*po*

English.	Ponape.	Hawaiian.
Outrigger	*tam*	*ama*. Melanesian *sama*
Oven	*um*	*umu*. Common
Powerful (supernatural)	*manaman*	*mana*. Common.
Path, road	*al*	*ala*. Common
Pillow	*uilinga*	*uluna*. Banks Is. and Solomon Is. *ulunga*
Rain	*ut*	*ua*. Common *usa*
Round	*ponopon*	*poepoe*
Scales of fish	*un*	*unahi*
Seven	*iju*	*hiku*. Common *fitu*
Side (of precipice)	*pale* (side of house)	*pali*, a precipice
Skin	*kili*	*ili*. Common
Sky	*lang*	*lani*. Common *langi*
Spirit	*ani*	*uhani*
Star	*uju*	*hoku*. Common *fetu*
Stand	*u*	*ku*. Common *tu*
Tooth	*ngi*	*niho*
Walk	*alu*	*alu*
Want	*anane*	*anoi*, to covet
Weep	*jongi*	*kani-kau*. Com. *tangi*
You	*ko*	*oe*.

The Parable of the Sower.—Luke viii., 5 - 8.

Hawaiian.	Ponape.
5. *Hele aku la ka mea lulu hua e lulu iho i kana hua; a i kona lulu ana, helelei kekahi ma kapa alanui; a hehiia iho la, a ua aiia iho la e na manu o ka lewá.*	5. *Joumot men ko lan kamoroka ta uan tuka kai: a ni a kamokamorok, akai mori ti pon kailan al; ap tiaka la, o manpir kai noma la.*
6. *A helelei iho la kekahi maluna o ka pohaku; a kupu ae la, mae koke iho la ia, no ka mea, aohe ona mau.*	6. *A akai mori ti pon paip; a lao uoja ta, ap mongi ti puoki jota lamuilamuir.*

7. *A helelei iho la kekahi iwaena o ke kakalaioa; a kupu pu ke kakalaioa, a hihia iho la ia.*

8. *A helelei iho la kekahi ma ka lepo maikai; a kupu ae la ia, a hua mai la ia pahaneri ka hua. A pau kana hai ana ia mau mea, kahea mai la ia, O ka mea peponio lohe, e hoolohe ia.*

7. *A akai mori ti nan uel en karer; a karer iang uoja ta kajokia la.*

8. *A akai mori ti nan puel mau, puai ta, kaparapar pan pak meapuki. A er pena a kaueue me pukat, ap majani, Me jalong a mia en rong uaja, i en rong.*

THE TENSILE AND COMPRESSIVE STRENGTHS OF MAGNESIUM.

By S. H. BARRACLOUGH, B.E., M.M.E.

[*Read before the Royal Society of N. S. Wales, December 4, 1895.*]

THE amount of experimental data available regarding the physical properties of magnesium is rather meagre, on which account the results of the tests herewith described may be of interest since there seems a possibility of the metal being in the future considerably used for constructional purposes. The following extract from an authoritative source will serve to indicate the most hopeful view that may justifiably be taken of the extent and nature of the future use of magnesium.[1] "Since the rolling of magnesium does not offer the slightest difficulty even in such forms as T I or angles, round or four cornered rods, or plates of 1 mm. thickness, and as pure magnesium is sufficiently resistant to atmospheric influences, and can be polished and easily cleaned, it lends itself on account of its lightness and relative strength to the construction of apparatus required to be made of metal and

[1] Journ. Soc. Chem. Indus., Vol. VI., p. 730.

also to be light—*e.g.*, nautical, physical and astronomical instruments. The working of magnesium requires heat. At 450° C. it can be rolled, pressed, worked, and brought into complicated forms. Screws and threads can be made from magnesium and these are considerably sharper and more exact than those from aluminium. Owing to its cheapness, magnesium can also be used in the manufacture of a variety of useful articles."

The present tests were made principally on rolled or drawn rods, nearly half an inch in diameter, together with a few confirmatory tests on specimens of the magnesian wire used for illumination purposes before the now more usual "ribbon" was introduced.

Tensile tests of six of the rods, made just as they were received from the manufacturer, gave the following results:—

No. of Test Piece.	Diameter.	Breaking Load lbs.	Breaking Load lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Ductility per cent	Modulus of Elasticity.
1	·433	3500	23,800	8,800	4·2	2,040,000
2	·433	3250	22,050	...	...	1,860,000
3	·442	3200	20,900	10,780	1·8	2,060,000
4	·435	2900	19,500	8,400	2·5	1,830,000
5	·424	3500	24,800	7,090	3·1	1,930,000
6	·432	3300	22,500	...	2·3	...

The extensions were measured by means of a Thurston extensometer, over a length of four inches. Two further tensile tests were made on specimens turned in the lathe to the dimensions stated, and with the following results. The metal can be turned with great ease.

No.	Diameter Inches.	Breaking Load lbs.	Breaking Load lbs. per sq. in.	Elongation per cent.	Contraction of Area per cent.
1	·335	2502	28,399	2·67	1·74
2	·351	2275	23,500	3·00	1·76

In these tests an attempt was made to obtain an autographic stress-strain diagram, but the apparatus ordinarily used for that purpose proved unsuitable for such a material as magnesium.

For the purposes of comparison several tests were made on specimens of ordinary commercial magnesium wire, giving results as follows :—

No.	Mean Diameter.	Breaking Load lbs.	Average Breaking Load lbs.	Average Breaking Load lbs. per sq. in.
1		16·7		
2		17·1		
3	·0245	17·0	16·87	35,800
4		17·1		
5		16·5		
6		16·8		

The compressive strength of three specimens was determined ; the dimensions of the pieces and the stresses being as follows :—

No.	Length Inches.	Diameter Inches.	Maximum Crushing Load lbs.	Maximum Crushing Load lbs. per square inch.
1	1·48	·415	5425	40,126
2	1·465	·415	5320	39,349
3	1·34	·414	5695	42,310

It will thus be seen that the average tensile strength of the magnesium rods is slightly over ten tons per square inch, with an elastic limit of four tons per square inch. In the form of wire the tensile strength of the metal is considerably higher, averaging nearly sixteen tons per square inch. This is probably a parallel case to the notable difference between the tensile strength of ordinary steel rods and of steel wires. The average compressive strength of the magnesium is about eighteen tons per square inch.

These figures differ slightly from those given as the result of a series of tests made at the Charlottenburgh Mechanical Laboratory.[1] There the average tensile and compressive strengths were 23·2 and 27·2 kilogrammes per square mm., or about 14·7 and 17·3 tons per square inch respectively.

An interesting comparison may be made between the strength as related to the density of magnesium on the one side and of

[1] Journ. Soc. Chem. Indus., Vol. VI., p. 730.

aluminium and steel on the other. These two metals are chosen as aluminium is no doubt a rival to magnesium on the score of lightness, and steel on account of its strength.

The form in which the comparison is made is one very commonly adopted.

Metal.	Weight per cubic foot lbs.	Tensile Strength lbs. per sq. in.	Length of a bar that just supports its own weight.
Magnesium ...	107·6	24,000	32,119 feet
Aluminium ..	168	26,000	22,285 ,,
Hard Struck Steel	490	78,000	22,922 ,,

The figures for the aluminium and the steel are taken from a paper on "The materials of aeronautic Engineering," read by Dr. Thurston at the Engineering Congress, Chicago, 1893.

NOTE ON SOME PRODUCTS FROM THE FRUIT OF *PITTOSPORUM UNDULATUM* AND FROM THE LEAVES OF THE PEPPER TREE *(Schinus molle)*.

By R. THRELFALL, M.A., Professor of Physics, University of Sydney.

[*Read before the Royal Society of N. S. Wales, December 4, 1895.*]

Pittosporum undulatum, so common in the bush around Sydney, not only produces flowers of exquisite scent, but bears an abundant crop of fruit. The fruit consists of slightly oval berries of about one centimeter in diameter. During the month of May these berries pass from a dark green to a bright orange hue, and in the following month usually split longitudinally, displaying a mass of dark coloured seeds or pips buried in a dark red mass of a pitch like substance. If the fruit is gathered when just ripe the pitchy mass is lighter in colour and I think rather more voluminous than is afterwards the case. Long before the fruit is ripe the pericarp and epidermis become more or less saturated with oil. The

epidermis is easily bruised by the fingers, and when this is done a strong scent peculiar to the fruit at once becomes noticeable. This odour resembles that of the rind of the tangerine orange, but is easily distinguished from the latter. During May 1894, I was struck with the great abundance of the fruit of *Pittosporum undulatum*, and determined to examine it in so far as my quite inadequate knowledge and opportunity permitted.

On cutting sections of the outer rind and examining them under the microscope, I expected to see globules of oil, but in this I was disappointed, either from incompetence as an observer or for some real reason which I do not understand, for subsequent observation showed that oil exists in abundance in this part of the fruit. Sections of the seeds showed a few globules of greenish oil, but not many.

I then compressed the ripe fruit in a screw filter-press, and from 500 grms. of fruit I obtained 70 cc. of a thick juice which was brownish-yellow in colour, smelt strongly of the oil and rapidly thickened on exposure to the air—or rather the surface did so.

On extracting this juice with alcohol and evaporating on the water bath, I obtained a fine green solution which had solidified by the next day to a hard green resin. This resin has a most pleasant smell, which so far as I know is quite peculiar to it, and which appears when the resin is heated—in the cold it is without any odour. During the evaporation of the alcohol the smell characteristic of the fruit was strongly marked, but it disappeared towards the close of the operation, whence I inferred that the odour of the fruit is probably due to the presence of an essential oil.

The juice also yields a watery extract, which when filtered and dried gives a brown mass. This brown substance has the bitter aromatic taste of the fruit. It was perfectly soluble in water and gave a blue-black precipitate with ferrous sulphate.

It was noticed that the seeds were not in any way crushed by the filter-press, and after several attempts it was decided to separate the seeds from the fruit, and to treat each part separately.

About three and a quarter kilos. of seeds surrounded by the pitchy matter were gradually collected, and an attempt was made to grind them in an iron mortar, but they were too hard to yield appreciably. Some of them therefore were pounded on an anvil with a heavy hammer. Finally, in the hope of softening the seeds, they were boiled in water for twelve hours, and afterwards a current of steam was passed through the still in order to remove any oil which might be removable by this process. The yield was a minute quantity of a white wax(?) with somewhat the same odour as that of the resin previously described. This wax was rather harder than tallow and is not perfectly soluble in alcohol. The water distilled over with the wax had a smell of the fruit, though this had degenerated to an unpleasant acrid odour.

The residue in the still consisting of the seeds and a trace of wax together with the watery extract was filtered, and a portion of the filtrate extracted with ether and with shale benzine. Both these substances produced such a heavy precipitate that the process was almost unmanageable. Neither ether nor benzine extracted any measurable amount of anything.

The watery extract was evaporated to dryness and yielded a brown mass which has not yet been further examined.

The seeds, when collected on a filter after undergoing the distillation process, were white and slimy on the surface, as if the resin had been partially decomposed. After stirring for an hour with a considerable quantity of alcohol the slimy mass dissolved. The alcoholic extract gave a mass of a dark red resin or pitch which has not yet been further examined except by heating. At first it yielded a smell as of turkey rhubarb, then of benzoic acid and finally an odour of the resin already referred to.

The seeds which had thus been freed from the pitch and soluble constituents were very hard, and an attempt was made to break them by compression in a mould on the testing machine. The press measured seven by seven inches and stood a pressure of 96,000 lbs. when it broke. The iron was greasy where the pressure

had acted most strongly, but no appearance of anything like a yield of oil was obtained, hence it was decided to abandon the pursuit of this oil for the time being.

An alcoholic extract of the husks from which the pitchy matter had been removed was prepared. This yielded an abundance of the green resin already referred to. It is clear therefore that both the characteristic resin and essential oil came from the pericarp and not from the seeds.

In order to obtain the essential oil of the pericarp some three kilograms of husks were prepared. These husks were placed in a copper still with about their own volume of water, and then distilled by means of a current of steam led in to the apparatus, the still itself being kept hot by means of a moderate flame. An abundant yield of oil was the result.

As it was now clear that nothing was to be gained by separating the pericarp from the seeds, I proceeded to submit the whole fruit to steam distillation in quantities of five to seven kilograms at a time. The greater part of the oil came over in the portions of water first collected. As the process went on, the yield soon grew to be so small as to be unremunerative, partly owing to the slight solubility of the oil in water. The yield is about 180 cc. of oil from 50 kilograms of fruit, which was the quantity operated upon by me. It takes about two and a half hours to extract the oil from each lot of fruit, starting with boiling water and passing steam at a pressure of three or four pounds per square inch through a half inch pipe into the still.

The oil obtained by distillation has at first a rather acrid odour, but this is possibly due to traces of the accompanying water, for on drying by means of fused calcium chloride the odour quickly improves, and in a few days becomes almost the same as that of the bruised fruit.

On submitting the dried oil to fractionation the following results were obtained. The oil began to boil at about 174° C., and 60–65 cc. were treated.

Fraction from 174° to 180·2° C., 22 cc., colourless.
" 180·2° to 185° C., 20·5 cc., colourless.
" 185° to 190° C., 8 cc., colourless.
" 190° to 200° C., 5 cc., colourless.
" 200° to 210° C., 3·5 cc., colourless.
" 210° to 250° C., 1·0 cc., faint greenish-yellow.
" 250° to 280° C., ·08 cc., bright yellow-green.
Above 280° C., residue ·57 cc., red with fairly strong green fluorescence.

During the process it was noticed that the oil appeared to begin to decompose slightly at about 200° C., this was also shown by the distillate changing sensibly in its odour above this temperature. The distillates below this temperature had sensibly the same odour as the oil before it was distilled. The residue when burned emitted the same odour as the green resin already referred to. The density of the oil was determined at 24·5 C. by weighing a bit of glass in it: the result was ·848 (24).

The refractive index was measured by means of a hollow prism and also by means of the refractometer as a check. The results were

μ_D . 1·4742 at 26° C.
μ_F . 1·4830 at 26° C.

The action of *Pittosporum* oil on polarised light was studied by myself to some extent, and thoroughly by Mr. Pollock with the assistance of Mr. Grant. The results of these observations is to show that *Pittosporum* oil in the crude but dry state rotates the plane of polarised sodium light in the same direction as cane sugar and to the extent of + 79·850 per decimeter at 24·4° C. I have to thank Professor Stuart for allowing us to use a polarimeter belonging to the Medical School.

The leaves of the introduced Pepper Tree (*Schinus molle*) were also examined with a view to discovering the source of the pungent odour so noticeable when the leaves are bruised. By distillation in steam I obtained 8·3 cubic centimetres of a thick oil from three

and a half kilos of the green leaves gathered in June. The oil was slightly yellowish and nearly as thick as vaseline oil. It had a pungent resinous and bitter taste, and a very strong scent of the pepper tree leaves.

Owing to the small quantity as yet obtained, no steps have been taken towards an examination. From the very strong scent of the oil, however, it is not unlikely that the odour of the leaves of the pepper tree may be wholly owing to it.

NOTES ON ANTARCTIC ROCKS COLLECTED BY MR. C. E. BORCHGREVINK.

By T. W. E. David, B.A., F.G.S., Professor of Geology; W. F. Smeeth, M.A., B.E., Assoc. R.S.M., Lecturer in Metallurgy and Demonstrator in Geology; and J. A. Schofield, F.C.S., Assoc. R.S.M., Demonstrator in Chemistry,

University of Sydney.

[With Plates XIII.–XV.]

[*Read before the Royal Society of N. S. Wales, August 7 and December 4, 1895.*]

Part I.—Introductory Notes about Antarctica.

(1) *Introduction.*—The region to which this paper refers is by far the largest unexplored land area in the world, its area being estimated by Dr. John Murray to be at least 4,000,000 square miles, and therefore greater than that of Australia. Situated between the volcanic zone of the Andes and the Taupo zone in New Zealand, it supplies several links to that chain of fire which, commencing at the north-western extremity of Antarctica, runs around the earth along the Andes and the volcanoes of Central America and Alaska, through the Aleutian Islands, Japan, the Kurile Islands, and various islands of the Pacific, through north-

eastern New Guinea, the Tonga Islands and New Zealand back to Antarctica, ending in the volcanic zone of Victoria Land. About fifteen extinct, five active, and three dormant (?) volcanoes have been recorded as occurring in the Antarctic Regions, (if the South Shetlands be included under this term), the highest known peak, Mount Melbourne, attaining an altitude of about 15,000 feet.

(2) *Summary of the History of Antarctic Exploration.*—Want of access to the necessary literature precludes us from doing more than traversing cursorily the records of a few of the chief Antarctic Explorers. The honour of being the first man to discover the Antarctic Continent probably belongs to Captain James Cook, who in the year 1772 reached latitude 71° 10′ S., in longitude 106° 54′ W., where he sighted the Great Ice Barrier, which forms the seaward boundary of Antarctica. Speaking of this discovery Sir James Ross says[1]:—"I confidently believe with D'Urville that the enormous mass of ice which bounded his view, when at his extreme south latitude, was a range of mountainous land covered with snow."

In 1819 William Smith in the brig *William* discovered the Archipelago of the South Shetlands, South of Cape Horn.

In 1820-23 Weddell visited the South Shetlands, including the the active volcano Bridgman. Powell, the discoverer of the South Orkneys, visited the volcanic island of Bridgman in 1822, and found it to be at that time two hundred feet high. Weddell, who visited it during the following year, estimates its height at four hundred feet, and describes the island as being of sugarloaf shape, whereas at the time of Powell's visit there was a crater on the west side of the island. Possibly the crater had disappeared at the time of the subsequent visit of Weddell, as he makes no mention of it. Weddell penetrated to 74° S. in 1823, thus attaining a higher latitude than Captain Cook, but he saw no land anywhere in that neighbourhood.

---

1 Voyage in the South Seas. By Sir James C. Ross. Vol. I., p. 276.

In 1831 Biscoe in the brig *Tula* discovered Enderby's Land. In 1839 Balleny discovered Balleny's Island, a volcano 12,000 feet high, and adjoining it the active (?) volcano of Buckle Island. In 1839 the important French Expedition, under Dumont D'Urville explored the South Shetlands.[1]

Syenite, occurring in needle-like pinnacles, was found at Smith Island, while this island as well as Livingstone, Greenwich, Roberts, King George and Elephant Islands were proved to be of primary schistose formation, traversed by intrusive igneous rocks. The trend of these rocks was ascertained to be north-east and south-west, dipping (?) at from 29° to 30°. Powell Islands were discovered to belong to a somewhat similar formation, being composed of phyllite-like talcites and quartzose talc rocks.

In the South Orkneys near Laurie Island the occurrence of a greyish-white limestone is recorded, as well as that of phyllite-like schists, their strike being north-north-west and south-south-east, and their angle of dip over 60°.

The granites and syenites, of which the New South Orkney Islands consist, were found to have contributed the greater number of the erratics observed on the coast of Terra del Fuego.

An interesting description is given in the above work of the remarkable volcanic crater, among the South Shetlands, known as Deception Island. The basin of the crater is submerged, the sea being sixty-seven feet deep at the centre of the basin, and the latter being about five miles in width measured at sea level: the maximum diameter of the crater ring measured at sea-level across its outer circumference is about eight miles, thus giving an average width of about one and a half miles for the portion of the crater rim above sea level. The crater is described as being built up of alternate layers of ice and volcanic tuff. Fumaroles were discovered to the number of at least one hundred and fifty,

---

[1] Voyage au Pôle Sud et dans l'Oceanie. Sur les corvettes *L'Astrolabe* et *La Zélée*, exécuté pendant les Années 1837-40. Géologie, Minéralogie et Géographie physique du Voyage, Vols. XXII.-XXIII., Paris, 1848.

the temperature of the water flowing from some being 140° Fahr. This expedition discovered Adélie Land. The mainland appeared to be completely swathed in snow and ice, but nine small islands off the mainland were found to be more or less free from ice, and to consist of granite and gneiss, the folia of which strike in an east and west direction.

In 1840 Commander Wilkes in the U.S.A. Corvette *Vincennes* discovered Wilkes Land. In January 1841, Sir James Clarke Ross made his memorable discovery of Victoria Land. With the object of trying to find the South Magnetic Pole, as he had already found the North Magnetic Pole, he forced his well fortified ships through the heavy pack ice which he encountered in latitude about 67° S., and longitude 174½° E. It was a very formidable pack. In four or five days, however, he forced his way through it, and entered comparatively open water beyond, a great ocean pool about six hundred miles in diameter. Bounding this on the west was the magnificent chain of snow clad volcanoes of Victoria Land. Ross traced the coast for five hundred miles southwards until he encountered the Great Ice Barrier terminating seawards in a sheer wall of ice, from one hundred and eighty to two hundred feet high, through which, in Ross' words, "he could no more sail his ships than he could sail them through the cliffs of Dover." His dredgings showed that marine forms of animal life, especially polyzoa, were abundant right up to the edge of the Great Ice Barrier. Ross states *(op. cit.)* that on January 19th, 1841, when off the coast of South Victoria, in latitude 72° 31′ S., longitude 173 39′ E., "the dredge was put over in two hundred and seventy fathoms water, and after trailing along the ground for some time was hauled in. It was found to contain a block of grey granite, composed of large crystals of quartz, mica and felspar, with apparently a clean and recent fracture, as if lately broken off from the main rock, and had probably been deposited by the agency of an iceberg. McCormick, the surgeon of the *Erebus*, frequently found fragments of granite in the stomachs of the penguins."

In 1874, H.M.S. *Challenger* visited the neighbourhood of the supposed Termination Land of Wilkes, and drift fragments were brought up by the dredge of granite, dioritic rocks, quartzites, clay shales etc. *Tetrasporeæ* were so abundant over wide areas as to give the sea a peculiar green colour, and the sea swarmed with diatoms. In 1883[1] the *Talisman* dredged from depths mostly of between 4,000 to 5,000 métres, common granite, hornblendic granite, pegmatite, granulites rich in muscovite and microcline, with two specimens respectively of diorite and diabase, and numerous specimens of gneiss and hornblendic gneiss. The gneisses were found to be more abundantly represented than the volcanic rocks. The following minerals are recorded as having been observed in the gneiss :—microcline, zircon, sphene, apatite, rutile, garnet, tourmaline, biotite, muscovite, magnetite, epidote, amphibole, pyroxene, diallage, and enstatite.

Amongst rocks probably of volcanic origin may be mentioned seven specimens of augitic labradorite rocks, two of basalt, and eight of andesites partly hornblendic, besides five specimens of pumice, eight of basic scoriæ more or less palagonitic, and ten specimens of very basic tuffs. Amongst metamorphic rocks dredged by the *Talisman*, may also be mentioned five specimens of mica schists with tourmaline, microcline, sphene and epidote, fifteen specimens of sericite and very epidotic quartz schists rich in rutile, besides argillaceous schist with crystals of biotite and garnet and numerous particles of graphite.

Amongst other rock specimens dredged were many representing undoubted sedimentary rocks, *e.g.*, sixteen of arkose very quartzose, nineteen of sandstones, and sixty-three of limestone. Some of the limestones are marble, some are oolitic, and thirty-one are fossiliferous, the fossils consisting chiefly of indeterminable bivalve shells. Some fragments of hard yellowish magnesian limestones contain sections of *Gyroporella*, and are therefore very probably

---

[1] Fouqué and Lévy—Comptes Rendus de l'Académie des Sciences, Janvier – Juin, 1886, CII., pp. 793 – 795.

of Triassic Age. Three specimens are almost entirely foraminiferal limestones of a markedly tertiary facies.

In 1893-94 the whaler *Jason* (Captain C. A. Larsen) visited the north-western portion of Antarctica. The important discovery was made by Dr. Donald,[1] of Lower Tertiary rocks with the fossil shells *Cucullæa*, *Natica*, and *Cytherea*, *in situ* at Cape Seymour. Fossil wood was also found imbedded in the Tertiary rocks at a level of three hundred feet above the sea. A new active volcano, named by Captain Larsen, Christensen Volcano, was discovered in latitude 65° 5′ S., longitude 58° 40′ W. On the sketch chart accompanying Captain Larsen's paper, another active volcano, Sarsee,[2] is shown, also Lindenberg Volcano [extinct (?)], and the four Seal Islands, all of which are considered to be of volcanic origin, if not dormant or extinct volcanoes.

We now come to the subject of the latest piece of Antarctic Exploration accomplished by Mr. C. E. Borchgrevink in the whaler *Antarctic*.

The following account is partly taken from the *Standard* of 2nd August, 1895, partly from notes kindly given us by Mr. Borchgrevink :—

The *Antarctic* was well fortified for ice work, her timbers being nowhere less than three feet in thickness, and actually not less than nine feet thick at the bows. She sailed from Melbourne on the 20th September, 1894. Mr. H. J. Bull accompanied the expedition as manager of the Antarctic Whaling Company, and Mr. C. E. Borchgrevink finding that there was no room on board for him in the capacity of scientific collector, pluckily engaged himself as an ordinary seaman. The pack ice was sighted on the 7th December, and on the following day the *Antarctic* was in latitude 58° 45′ S., longitude 171° 30′ E., and with vast streams of ice driving all around. When the *Antarctic* entered the pack ice the temperature of the air was 25° Fahr., and that of the water

---

[1] J. Murray—Geogr. Journ. Vol. III., No. 1, Jan. 1894, pp. 10, 11.

[2] Geogr. Journ. 1894, IV., No. 4, p. 333.

28° Fahr. Penguins were about in great numbers, and no difficulty was experienced in killing some of them.

On the 14th December, in latitude 66° 44′ S. and longitude 164° 0′ E., as the *Antarctic* approached Balleny Island, the ice floes greatly increased in size, and some of them were observed to carry stones and earth. So thick and dangerous was the ice that a vessel, dependent wholly upon sails, could not have existed, and even with steam those on board ran very considerable risk, and had one or two narrow escapes. They decided to run eastward, following in the track of the *Erebus* and *Terror*. On Christmas Eve they saw the midnight sun in latitude 66° 47′ S. and longitude 174° 8′ E., and at midnight on the 31st December the sun was again shining brightly.

Altogether they were thirty-eight days in working their way through the pack ice, and then they got into a clear, smooth, open expanse of sea. They steered straight for Cape Adare in Victoria Land, which they first sighted on Jan. 16. Mr. Borchgrevink describes it as a square bluff of basaltic rock. The temperature of the air here was 32°, and of the water 30°, and the sky was perfectly clear. Cape Adare rose to a height of 3,779 feet. Near Mount Sabine a peak was sighted clear of snow, considered to be a volcano recently in eruption.

On January 18th, they sighted Possession Island, where Sir James Ross landed fifty-four years before and planted the British flag. They found an immense quantity of penguins, and a large portion of the island, which they judged to be about three hundred and sixty acres in extent, was covered with a deep layer of guano. Small plants were found there by Mr. Borchgrevink growing on the rocks up to thirty feet above sea level. These have subsequently been identified as lichens.

On the 20th February they steamed still further southward, and sighted a new cape which they named Cape Oscar, in honour of the King of Sweden and Norway, whose birthday it happened to be. On the 22nd they were in latitude 74° S., and no whales

being visible they decided to return northwards to Cape Adare, where they landed, being the first human beings who had ever set foot on that territory. Their landing place was a sort of peninsula, which formed a complete breakwater for the inner bay, through which they steered. Immense swarms of penguins were on the cape, on which they nested as high up as 1,000 feet. Mr. Borchgrevink and his party after landing, collected specimens of the rock, and they also found some signs of vegetation, consisting of lichens (?) like those met with by them at Possession Island.

Throughout the whole of their voyage they had a comparatively high temperature, and they met with great numbers of sperm whales. The minimum temperature which they encountered within the Antarctic circle was 25° Fahr., and the maximum was 46°, while all through the ice pack it kept at 28°. The mean temperature for January 1895 was 32·5° Fahr., and for February 30° Fahr.

While at Possession Island and Cape Adare Mr. Borchgrevink collected specimens of the different varieties of rock obtainable at those localities. Several of the specimens from Cape Adare are in the form of waterworn pebbles, which were picked up by Mr. Borchgrevink on the shores of that headland.

(3) *Summary of Antarctic Geology.*—The observations of the Antarctic explorers mentioned above prove that (*a*) eruptive, (*b*) sedimentary, and (*c*) metamorphic rocks are well represented in Antarctica. If the (*a*) *Eruptive rocks* be divided into respectively plutonic, and volcanic groups, we find that the former comprises granite, pegmatite, granulites rich in microcline and muscovite, syenite, diorite, diabase etc., and the latter pumice, andesites partly hornblendic, augite-labradorite rocks (augite-andesites ?), basalts, basic scoriæ, palagonite tuffs.

(*b*) *Sedimentary rocks*—These comprise the *Cucullæa* rocks of Cape Seymour, with fossil wood of Lower Tertiary Age, numerous fragments of limestone, partly molluscan, partly foraminiferal, the latter Tertiary, the former of doubtful geological age, some more

or less incoherent, some oolitic, some in the condition of marble. Besides these are the fragments of hard yellowish magnesian limestone with *Gyroporella*, probably Triassic, the Palæozoic (?) greyish-white limestones of the South Orkneys, fragments of various sandstones, arkose, quartzites, and clay shales.

(*c*) *Metamorphic rocks*—These appear to be abundantly represented and comprise :—gneisses, some hornblendic, containing zircon, microcline, sphene, apatite, rutile, tourmaline etc., mica-schists with tourmaline, microcline, sphene and epidote : sericite quartz-schists, epidotic quartz-schists rich in rutile, argillaceous schist with crystals of biotite and garnet, and numerous particles of graphite, phyllite schists and talc schists.

With regard to the volcanic zone of Antarctica the following is a list of the volcanoes at present known to us :—

1. Balleny Island	...Dormant (?)...	...	12,000 feet high.
2. **Buckle Island**	**...Active (?) ...**	**...**	**Small.**
3. Mount Sabine	...Extinct (?) ...	...	9,500 feet ,,
4. Cone observed by Borchgrevink near Mt. Sabine apparently recently in eruption, **Active (?).**			
5. Mount Herschell	...Extinct ...	...	14,000 feet (?) ,,
6. Mount Melbourne	...Extinct(? large crater).		
7. Mount Erebus	...Active ...	...	12,367 feet (?) ,,
8. Mount Terror	...Extinct (?) ...	...	10,884 feet ,,
9. Mount Haddington	Extinct (?) ...	...	7,050 feet ,,
10. Cockburn Island	...Extinct (?) ...	...	2,750 feet ,,
11. Paulet Island	...Active ..	...	750 feet ,,
12. Etna Island	...Extinct (?) ...	...	1,300 feet ,,
13. Bridgman Island	...Active cone	...	400 feet (?) ,,
14. Apsland Island	...Extinct crater.		
15. Astrolabe Island	...Extinct crater	...	1,000 feet (?) ,,
16. Deception Island—Large partly submerged crater with numerous fumaroles, dormant (?)			800 – 1,800 ft. ,,
17. Christensen Volcano	Active ...	...	Small.
18. Sarsee Volcano	... Active ...	...	,,

19.	Lindenberg Volcano	Extinct (?)...	... Small
20. 21. 22. 23.	The four Seal Islands,	extinct (?)	... ,,

As regards the general distribution of these volcanoes, we may here quote from a previous paper by one of us forming part of his Presidential Address to the Linnean Society of New South Wales for 1895, pp. 155 - 156 :—"The volcanoes of Victoria Land show a tendency to linear arrangement. From Mount Sabine to Mount Melbourne the trend is south-south-westerly. Mount Erebus and Mount Terror lie almost due south of Mount Sabine. Further north from Mount Sabine the great earth-fold, on the *septum* of which this chain of volcanoes is situated, probably bends a little westwards, as shown partly by the surroundings, partly by the position of Balleny's Island. North-west of Balleny's Island the great fold trends perhaps to the knotting point between the Tasmanian axis of folding, described in the address just referred to, and that of New Zealand, the former perhaps running through Royal Company Island, and the latter through or near Auckland Island and Macquarie Island. The knotting point would probably be somewhere (approximately) near the intersection of the 60th parallel of south latitude with the 150th meridian of longitude east from Greenwich. It would thus join the line of extinct volcanoes along East Australia on the west, and perhaps the active volcanic zone of the North Island of New Zealand, or at all events the fold which bounds that continent, on the east.

Traced in the opposite direction, the volcanic zone probably runs through Seal Islands, the active volcanoes of Christensen and Sarsee, and through Mount Haddington, an extinct volcano in Trinity Land, to Paulet and Bridgman Islands, active volcanoes. The volcanic zone bends easterly from here on account of the easterly trend in the fold, which appears to make a loop towards South Georgia before it swings back towards Cape Horn. That there is a real easterly trend in the earth-fold at Trinity Land

and the South Shetlands is proved by the observations made by the *Astrolabe* and *Zélée* expedition, which record a strike in a north-north-east and south-south-west direction for the greyish-white limestones and phyllite-schists at the South Orkneys. Towards Cape Horn from near South Georgia the fold probably trends west-north-westerly, then follows an approximately meridional direction parallel with the chain of the Andes. It may be noted, however, that whereas the *Erebus* chain of Victoria Land is on the east side of the fold, the Christensen-Bridgman group are apparently on the opposite side. This may be due to the fact that at the latter locality the eastern slope of the fold is steeper than the western, as seems probable from the presence of the deep ocean abyss east of Graham's Land, as shown on Dr. Murray's map. It is probable, therefore, that the volcanic chain of Victoria Land will continue towards the South Pole, probably bending somewhat to the eastward, and will thence change its position to the fold on the other side of the Antarctic continent, so as to run through the Christensen-Bridgman line of volcanoes. In any case it is almost certain that high land, covered of course more or less by snow and glaciers, will be found at the South Pole."

The additional information as to the geology of Antarctica furnished by the collections submitted to us by Mr. Borchgrevink is detailed below :—

Part II.—Petrology of the Rocks collected by Mr. C. E. Borchgrevink from Cape Adare, Victoria Land, and from Possession Island.

A.—Specimens from Cape Adare.

Garnetiferous-Granulitic-Aplite, (No. 4).

This rock is the only representative of the acid-group among the specimens. In the mass it is a white, holocrystalline, aggregate of quartz and felspar granules. Numerous small, well-crystallized red garnets are present, also numerous crystals of black tourmaline. In section the granulitic texture is very

marked, and the felspar granules are seen to consist largely of microcline. The hatched twin lamellæ are very irregular and wavy and suggest that the rock has been under pressure. There is a small amount of triclinic felspars which appears to lie between albite and oligoclase. One section of the latter shows a remarkable twin structure (*Plate* 13, fig. 1), the outline is rudely rectangular and the grain is divided into four equal areas by lines joining the middle points of the sides. Each area is finely lamellar, and extinguishes simultaneously with the one diagonally opposite to it. A possible explanation may be that it is a section approximately parallel to the macropinacoid (100) divided into two halves according to the Carlsbad law, and again divided into two halves, one of which is reversed on the other by turning round a normal to 001, according to the Mannebach law. In addition to this each of the four areas exhibit albite lamellation. Some of the felspars show numerous fine parallel cavities probably of the nature of solution planes.

The quartz grains have some liquid enclosures but not many, and also some very fine needles of a mineral which has not been determined. Stray flakes of muscovite have been noticed.

Among the accessory minerals the garnets do not require further notice. The tourmaline occurs in well shaped prisms the pleochroism being pale pinkish-brown to very dark slaty-purple.

Included in the other minerals are numerous highly refracting grains and prisms, all practically colourless. Some of these must be referred to topaz, although the optical sign appears to be negative instead of positive, as is more usual. One piece in particular, (*Plate* 13, figs. 2*a*, 2*b*) has the outline of a cross section of topaz and gives a good figure in convergent light. In this, from the shape of the section, it can be seen that the optic axial plane is the macropinacoid, and that the sign is negative while the axial angle is somewhat smaller than usual. If this mineral is a topaz, it would appear that in addition to the change of sign, the plane of the optic axes has taken a position at right angles to the normal one. It is an interesting point in connexion with this,

that we have found, among some sections cut for stauroscopic investigation, a specimen of topaz in which the optic axes make a very small angle with each other (not more than a few degrees) and that the optical sign is negative. It may be that under certain conditions topaz changes its axial angle, and after passing through zero the axes open out in a plane at right angles to their former position with changed sign.

Besides some apatites and zircons there are some grains with extremely strong double refraction. One of these, a small prism showing pyramid faces at one end, gives colours of the seventh order in polarized light (*Plate* 13, fig. 3). The presence of some prismatic cleavage lines render it probable that it is rutile.

There are a few tabular crystals of anatase, and some grains, with somewhat lower double refraction and without cleavage, may most probably be referred to cassiterite.

Trachyte, (Nos. 1 and 2).

Compact, greenish-grey in colour, somewhat fissile. Sp. gr. 2·49.

Analysis yielded the following composition :—

SiO_2	=	61·01
Al_2O_3	=	16·62
Fe_2O_3	=	3·55
FeO	=	2·81
MnO	=	·55
CaO	=	3·27
MgO	=	·06
Na_2O	=	5·92
K_2O	=	5·22
Water (ignition)	=	1·13
		100·14

Phosphoric acid and chlorine present in small quantities.

Under the microscope the rock is seen to be composed principally of sanidine microlites. There is a small proportion of lath-shaped triclinic microlites and of cryptocrystalline interstitial material.

(*Plate* 14, fig. 1). The sanidines are apparently all tabular in form, some slices showing nothing but tabular sections while others yield only lath-shaped ones.

The ferro-magnesian constituent is represented by an ægirine which is present in considerable quantity (probably nearly 25% of the whole bulk). It exhibits brownish-green to bluish-green pleochroism with a small extinction angle. It is uniformly distributed in minute angular patches moulded on the felspars with here and there a tendency to an elongated prismatic habit. In places it shows ophitic structure on a small scale. The only porphyritic constituents are a few rounded grains of this same ægirine and a few large grains of magnetite.

As accessory constituents there are a number of minute flakes of a brown biotite, some needles of apatite included in the felspars, a few zircons and a little magnetite.

Glassy Augite Andesite (?) No. 11.

Greyish-black in the mass and has the appearance of a fine grained andesite or basalt.

There are but few porphyritic constituents. Some corroded fragments of felspar, apparently monoclinic, and some grains of a pale augite with faint pleochroism —yellowish- to pinkish-brown. There are one or two patches of magnetite (opacite) granules with traces of brown hornblendic material remaining.

Next to these in point of size we have a sparsely scattered crop of small lath-shaped felspars, the majority of which are simply twinned, but a few show lamellar twinning and appear to be oligoclase. The base appears to be glassy, but is generally not quite isotropic and gives the impression of being in a state of strain. It is quite colourless and in many places indefinite plates of felspar material seem to have partially developed.

This base is filled with very minute augite crystals. They are for the most part well formed crystals, with short prismatic habit, pale green in colour, and appear to have a small angle of extinction.

They are too minute to be certain of pleochroism. In addition to these there is much magnetite dust.

This rock ought perhaps to be classified as a trachytic andesite owing to the number of apparently monoclinic felspars present. The amount of glassy base present renders its nomenclature a matter of uncertainty which can only be settled by chemical analysis for which there has not been time up to the present.

Vesicular Andesite Glass, No. 13.

This is a highly vesicular fragment which on examination proves to have many points in common with the glassy andesite No. 11, and may well be considered as a portion of the same flow. The porphyritic constituents are quite similar to those in No. 11, with the exception that we have here some hornblendes preserved with a ring of opacite granules round them, while in No. 11 the hornblende has practically completely disappeared. The lath-shaped felspars are not so numerous, but are still for the most part simply twinned. The base is faintly coloured and somewhat more glassy while the incipient felspar plates are not noticed.

The minute augite crystals are perhaps quite as numerous as in No. 11, but are even smaller while the magnetite and opacite dust is more diffused.

Basaltic Andesite (No. 6).

In the mass fine-grained, very dark grey in colour, with but few porphyritic crystals. Sp. gr. 2·78.

In sections the ground mass is cryptocrystalline, and contains a dust of magnetite and minute augite granules. Above this in the scale of crystallization is a crop of forked triclinic microlites, giving extinction angles approximating to labradorite. There are also many small square and rectangular sections of felspar, most of which show only simple twinning.

Some large crystals of magnetite are present, and a number of medium sized yellowish brown augites. One or two grains of olivine were noticed enclosed in augite. There are also some

corroded crystals of a rich brown hornblende, which are surrounded by a ring of magnetite (opacite) dust, which varies in amount from a thin layer to a complete absorption of the original mineral. (*Plate* 14, fig. 3.)

Olivine-Dolerite, No. 14.

This rock has suffered considerable alteration. The felspars are lath-shaped, not much decomposed, but the broken and irregular lamellæ give evidence of considerable crushing. These felspars have a tendency to aggregate into radial or fan-shaped groups which might be considered as a poor attempt at 'centric' or 'ocellar' structure.

The augite is brown in colour, the depth increasing toward the periphery of the grain. It occurs in irregular grains partly moulded on the felspars, and giving rise in places to ophitic structure. Most of it is fairly fresh, but in places it has been converted into a felted mass of chlorite fibres, and possibly also serpentine or other ferruginous silicates.

The olivine is in large grains, frequently with idiomorphic contours. These have for the most part been converted into serpentine, without separation of magnetite dust, but coloured in patches by homogeneous aggregates of chlorite fibres.

Magnetite crystals are present, together with irregular masses of secondary magnetite. Specular hæmatite seems to be present also, the brilliant faces of the crystals being noticeable in reflected light; some of this is possibly micaceous ilmenite.

Numerous slender needles of apatite traverse all other constituents, and there are needles of what appears to be an actinolithic mineral also present.

Olivine Basalt (Nos. 3*a*, 3*b*).

Compact, greyish-black with phenocrysts of augite, olivine and plagioclase. Sp. gr. 2·92.

In section the rock is clear and fresh. The ground-mass fine in texture and composed of plagioclase microlites, minute grains

of brownish-green augite moulded on the felspars, and magnetite dust.

The porphyritic constituents are :—Plagioclase (chiefly labrodorite), some of the crystals being zoned and others appear to be made up of patches of felspar of different composition, forming a large lath-shaped section. Some of these patches have all the appearance of sanidine. Augite, pale brown in section with idiomorphic contours. Olivine, generally in rounded grains, occasionally idiomorphic, and showing no alteration to speak of. There are also some large grains of magnetite. Some of these have a coarsely arborescent structure, the spaces between the branches being occupied by felspar and augite similar to the ground-mass. This would seem to point to the constituents of the ground-mass having started to crystallize before the grains of magnetite had completely separated out. (*Plate* 14, fig. 2.)

Olivine Basalt, (No. 7).

This specimen is a vesicular pebble of a reddish-brown colour. Sp. gr. 3·07.

Under the microscope the rock is seen to consist of a fine-grained ground-mass much stained with ferruginous decomposition products, and carrying numerous phenocrysts of augite, olivine and magnetite. The scarcity of felspar is at once apparent, no crystals of any appreciable size being present. The ground-mass however, contains a considerable number of very small felspar microlites. These together with much very finely granular augite and magnetite dust make up the ground-mass, little if any glass being discernible.

At first the comparative scarcity of felspar would suggest that the rock approached a limburgite in composition. The following analysis shows that it must be retained in the basalt group :

SiO_2 = 45·13%
Al_2O = 18·13
Fe_2O_3 = 12·94
CaO = 11·23

MgO	=	7·33
K_2O	=	·98
Na_2O	=	2·14
H_2O	=	2·18
		100·06

The percentage of Al_2O_3 is high and implies the presence of felspar, either actual or potential. As there is little glass present it is probable that the augite, which is by far the most prevalent constituent, is itself highly aluminous.

The porphyritic augites are frequently broken but not much corroded. All exhibit shelly zoning, there being generally two or three thin shells round each crystal. In some cases where the crystal has been fractured these shells continue round the fractured edge, showing that they have formed subsequently to the breaking of the original kernel. This kernel is frequently twinned and is greenish-yellow in colour. The angle $c : c = 45°$; this increases in other outer shells up to 55° in the outermost. Zoning is apparent in ordinary light, owing to the outer shell being of a decided yellow colour, but whether this is due to change in composition or merely to staining is not clear, though the former is probable, from the sharpness and uniformity of the coloured shell. One crystal differs from the majority in having a well marked shell with a greater angle of extinction than the kernel and outside this a thin shell having the same extinction as the kernel.

The olivine is all porphyritic, idiomorphic outlines being common. All the crystals exhibit a curious structure. They are traversed by a dense rectangular network composed of strings of magnetite grains which here and there show octahedral faces but are less regular than skeleton crystals. (*Plate* 13, fig. 4.)

The main axes of these strings are apparently parallel to the axes, a, and b, the shorter offsets being parallel to the vertical axis. The olivine matrix is perfectly colourless and fresh, showing no decomposition and none of the usual irregular cracks. In

places there are thin films of what is probably micaceous hæmatite making the olivine a brilliant transparent red.

In many of the crystals the enclosed iron oxides have been attached and converted into opaque red hæmatite, so that the whole crystal appears of an opaque red by reflected light. The larger crystals of magnetite have suffered in the same way, and the opaque red dust has spread over much of the ground-mass.

Limburgite (No. 9).

In the mass this rock is of a dark grey colour, compact with minute irregular cavities, and shows phenocrysts of augite and olivine. Sp. gr. 2·94.

It has very much the appearance of an ordinary olivine basalt. On microscopic examination, however, felspar was found to be entirely absent. Porphyritic augites and olivines are abundant; they are clear and fresh, and show crystal boundaries. These augites are yellowish to pinkish-brown in colour, generally zoned and frequently twinned. Then we have a large crop of much smaller augites with a few small olivines, and finally there is a base of fine granular augite and greyish to brown intersertal glass dusted over with granules of magnetite. (*Plate* 15, fig. 3.)

The colour of the glass varies in patches: in places it seems almost entirely absent, and elsewhere we find it in brown angular patches filling the spaces between the second generation of augites. This glass is perfectly isotropic, but contains a dust of dark particles. Throughout the mass there are little irregular cavities which would appear to be contraction rifts consequent on crystallization. Into these the augites of the second generation project with very good crystal boundaries. These cavities are filled with a colourless isotropic mineral with a few needle-like inclusions. This is most probably analcime. Treated micro-chemically with HCl it is decomposed, yielding a good crop of NaCl crystals and gelatinous SiO_2. The separated silica is richly stained by malakite green.

As to the nomenclature of this specimen, its mineralogical constitution practically entitles it to a place among the limburgites, though it is undoubtedly more stony in texture than is usual with these rocks.

A partial analysis gave the following results :—

SiO_2 = 38·44%
Al_2O_3 = 19·88
Fe_2O_3 = 13·46

Some oxide of manganese is included with the alumina. This shows that the rock is ultrabasic in composition. The high percentage of alumina is accounted for by the analcime which is present in considerable quantity.

Limburgite, (No. 10).

This rock is not unlike No. 9 in general appearance, but its texture is finer. Sp. gr. 2·91.

Under the microscope it is seen to be a highly glassy rock, the glass being very free from crystallites and of a rich brownish-yellow colour. Contained in the base are porphyritic augites and olivines, and a second generation of smaller augites similar to No. 9. Numerous small granules of magnetite are also present. (*Plate* 15, fig. 4).

It is possible that this rock is but a more glassy portion of the mass from which No. 9 has come, and that this glass holds potentially the granular augitic base which is seen developed in the latter rock.

A partial analysis, for comparison with No. 9, gave the following :—

SiO_2 = 38·99%
Al_2O_3 = 11·72
Fe_2O_3 = 15·26

The percentage of alumina in this is much less than in No. 9, and probably represents more accurately the common magma, as in this rock no analcime, so prevalent in the other, is observed.

Basic Tuff, (No. 8*a*, 8*b*).

A hardened tuffaceous material, light-brown in colour, containing numerous darker angular fragments. Under the microscope is seen to be composed of numerous irregular fragments of various basic volcanic glasses. These vary in colour from light to dark brown, and are all amygdaloidal, the vescicles being filled or partially filled with colourless isotropic material. Some of the lighter fragments are almost pumiceous in texture, while a few consist of almost compact dark brown glass.

All the fragments contain minute lath-shaped felspars with a parallel arrangement in each piece, while the more glassy ones contain trichites in addition. The matrix is comminuted material of the same nature as the fragments, and contains a few large angular pieces of felspar.

No. 8*c* is very similar to the foregoing but is more porous, the vesicles being without amygdaloidal infillings.

Nos. 12 and 15 are fragments of scoriaceous lavas, some of which approach pumice in character. They are probably of intermediate composition, but have not been examined in detail.

Mica Schist, (No. 5.)

A fine grained rock, consisting of quartz and dark brown mica, with strongly marked schistose characters and easily fissile. In thin sections the rock appears to be made up principally of clear granules of quartz and flakes of biotite (*Plate* 14, fig. 4). The biotite forms about 20% of the whole mass and is perfectly fresh and strongly pleochroic. In addition to these constituents there is a small amount of a white mica which appears to be muscovite. There are also numerous small but beautifully formed prisms of brown tourmaline as well as zircon, apatite, magnetite, some pseudomorphs of pyrites in oxide of iron, and a few grains of a green spinel, probably pleonaste. Some felspar is also present, and possibly a member of the scapolite group.

The bulk analysis of the rock yielded the following results:—

SiO_2	...	= 71·43%
Al_2O_3	(P_2O_5)	= 11·03
Fe_2O_3	...	= 1·81
FeO	...	= 2·56
MnO	...	= ·52
CaO	...	= 4·07
MgO	...	= 2·44
Na_2O	...	= 2·10
K_2O	...	= 2·77
H_2O (on ignition)		= 1·44
		100·17

Phosphoric acid, chlorine and fluorine are present in small quantities.

The percentage of lime is notably large and a partial analysis of the biotite was made to see whether it contained any lime. This yielded the following:—

SiO_2	= 37·70%
Al_2O_3	= 20·74
Fe_2O_3	= 19·03
MnO	= 2·03
MgO	= 8·06

The iron present as FeO was not determined. It was found to contain no lime.

The above analysis shows that the mica, which has a decided bronze lustre, lies between biotite and lepidomelane in composition. It was also found to be uniaxial. The high percentage of MnO is noteworthy and probably accounts for all the manganese found in the bulk analysis of the rock. (We may mention incidently that all the specimens of these Antarctic rocks which have so far been submitted to analysis contain appreciable quantities of manganese).

Lime being therefore excluded from the mica it became necessary to search for it elsewhere. No trace of twinning, which

would indicate a felspar, is to be found among the colourless granules; nevertheless some of them were found to be biaxial in convergent polarized light. Further, in the neighbourhood of joint planes, some of these granules are seen to be slightly decomposed, indicating that they are silicates and not quartz.

These silicates, from their resemblance to the quartz grains, when not decomposed, may be either felspars or scapolites or both. The fact that many of them are biaxial may reasonably be taken as indicating felspar, notwithstanding the absence of twinning, for the secondary felspars in schists are frequently untwinned and much resemble quartz in thin sections. The question then arises as to whether a member of the scapolite group is also present. To try and settle this, a prolonged separation of the mineral constituents was made. A few heavy minerals came down first, then the tourmaline; close on this came the dark mica, and immediately after it the muscovite. The bulk of the rock, which now consisted of colourless grains only, remained. For a long time we tried to separate this into its different constituents but failed, as they all floated or sank together. It followed therefore that the quartz, felspar and other silicates, not only resembled each other under the microscope but were also of equal density.

Separation by this method having failed, and the silicates being but slightly attacked by acids, the isolation and identification of a scapolite (if present) is not feasible. Nevertheless certain general arguments render the presence of such a mineral very probable. In the first place a felspar with the sp. gr. of quartz would have a composition approaching that of oligoclase or andesine. In such a felspar the proportion of CaO does not exceed that of Na_2O, and if we assumed that all the Na_2O was present in felspar, this would account for only 2·1 % of CaO, leaving a balance of 1·97 % unaccounted for. We are therefore in need of a silicate which, under the microscope resembles quartz, has the same sp. gr. as quartz, and in which the amount of CaO, or the proportion of **CaO to Na_2O, is large.**

Now certain members of the scapolite group are the only minerals with which we are acquainted which entirely satisfy the conditions, and on these grounds we think it highly probable that such a mineral is present.

The question of the pre-metamorphic condition of a schist, such as the present one, is of great interest, but unfortunately little can be done towards its elucidation from mere hand specimens. One or two suggestions may, however, be made. From the bulk analysis this mica schist appears to have the composition of an acid igneous rock so far as its more stable constituents (SiO_2 and Al_2O_3) go. In other constituents there are important differences. For example, the amount of CaO and of MgO is largely in excess of, and the amount of alkalis falls far short of, that usual in acid igneous rocks. Now this diminution of the alkalis and increase of the alkaline earths is suggestive of denudation and sedimentation, and lends colour to the suggestion that this rock may be a metamorphosed sediment.

Again the numerous tourmalines present indicate, probably, thermal metamorphism under the influence of an highly heated acid rock from which boric acid and fluorine might be derived. (In the granulitic aplite No. 4, we have evidence of the presence of such an igneous mass—containing much tourmaline—in the district). One may therefore suggest with some probability that this mica-schist has been previously a sedimentary rock which has taken its present form under the influence of a neighbouring mass of highly heated acid magma.

B.—Specimens from Possession Island.

Amygdaloidal Trachyte, (No. 9).

Grey in colour with numerous irregular cavities, many of which are filled with yellowish and white materials. The texture is uniform, giving in section a mass of small lath-shaped felspars which appear to be sanidine and oligoclase. Between these there is a fair amount of colourless glass containing magnetite and very minute grains of highly-refracting greenish material, probably

augite. The flow structure is distinct, and the cavities and amygdaloids are irregularly elongated parallel to its direction. These amygdaloids consist of a very irregular layer of brownish doubly-refracting material which fuses easily and gelatinizes easily with HCl even in the cold, and is most probably natrolite.

The portions inside this layer are generally filled with colourless sectors of material which exhibits faint anomalous double-refraction, and may probably be analcime. In some of the larger ones the centre is occupied by calcite surrounded by analcime which is again surrounded irregularly by natrolite. The natrolite exists in minute fan-shaped aggregates.

Augite Andesite, (No. 12).

Rock brownish in colour, considerably decomposed and porous. Small red grains indicate oxidation of magnetite crystals, and the general brownish tone due to oxidation of magnetite dust. There is not much actual staining of other constituents. Under the microscope appears to be an andesite of fine texture.

The base consists of felspar microlites, a great number of smaller prisms and grains of yellow augite and magnetite (mostly converted to reddish oxides), and a fair amount of granular intersertal glass, almost colourless and containing highly refracting globulites. There are some porphyritic crystals of brownish augite the outer shells of which are of a strong yellow colour similar to that of the small augites in the base. This is probably due to oxidation of the FeO. There are some dark patches in the base, some with regular outlines, which may represent the debris of another constituent, possibly a hornblende.

Basalt, (Nos. 1 and 2).

These are specimens of a fine, dark, compact basalt, with a few porphyritic crystals of black augite. Sp. gr. 2·82, 2·86.

In section, flow structure is apparent from the parallel arrangement of the small lath-shaped felspars. The texture is microcrystalline with a certain amount of intersertal glass of a brownish

colour. Numerous small brownish-red olivines are present as well as minute crystals and grains of a pale augite, and much magnetite dust. The glass contains numerous globulites and microlites, but nothing of special interest.

Basalt, (Nos. 3 and 7.)

These specimens seem identical, save that No. 3 is slightly vesicular, while No. 7 is fairly compact. Colour greyish-black. Base glassy with patches of finely granular augite. Small lath-shaped felspars abundant, also small brownish-red olivines. Porphyritic constituents scanty, consisting of one or two rich brown hornblendes surrounded by a considerable resorption layer of opacite granules mixed with granules of augitic material; and a few fair sized grains of a greenish augite. These specimens bear a strong resemblance to Nos. 1 and 2 in mineralogical constitution.

Basalt, (No. 5.)

Fine in texture with glassy base containing magnetite, minute pale augite, felspar microliths, and some small olivines decomposing into brownish-yellow serpentine. The usual small lath-shaped felspars are present; some porphyritic grains of pale augite, and some pseudomorphs of hornblende in opacite and augite granules. One of these represents a large crystal of hornblende, and some of the original mineral remains. This is clear and fresh, and shows a greenish-yellow to brown pleochrism (*Plate* 15, fig. 1). Near the centre of the pseudomorph a large patch of the rock base is included. The constitution of this pseudomorph is peculiar. There is an outer zone of opacite, and almost colourless augite granules preserving the idiomorphic outline of the original hornblende. Inside this there is a zone of varying width formed of fucoid-like growths standing at right-angles to the sides. These are dark brown in colour, translucent, and slightly pleochroic (*b* and apparently traversed by strings of opacite granules. It is probable that they consist of thin leaves of a brown oxide of iron.

Basalt, (No. 6).

Fine in texture, with glassy base nearly colourless and containing numerous globulites and grains of highly refracting material,

which is probably augite. Also magnetite dust, a large crop of lath-shaped felspar microlites and many small brownish-red olivines. Porphyritic constituents absent. There is, however, in one of the sections a crystal of zoisite, about 0·75 mm. long by 0·5 mm. broad (*Plate* 15, fig. 2). This is perfectly colourless and conspicuous by its very low double-refraction, high index of refraction, and rhombic characters. The section is six-sided, showing two prism faces and four pyramid faces. The cleavage parallel to 010 is well shown and a series of somewhat curved parting planes at right angles to the vertical axis. In this particular section the greater elasticity is parallel to the axis *c*. There are some smaller sections of this mineral giving rhombic and trapezoidal outlines.

Basalt, (No. 8).

This rock in the mass presents a curious foliated appearance. It seems to be made up of little irregular ovoid lumps, about 5 mm. by 2 to 3 mms., together with less regular fragments into which it easily breaks up. The ovoid pieces all lie with their longer axes parallel and a face at right angles to these axes was polished. It was then seen that the ovoid lumps gave rise to dull round spots fairly regularly distributed over this surface. They are of softer material than the portions surrounding them, and form centres from which irregular cracks radiate out through the surrounding layers (*Plate* 13, fig. 8).

It would thus appear that the rock has split up into a number of irregular ovoid lumps, the longer axes of which are all parallel, that most of these have a kernel of softer material the outer evelope being traversed by irregular radial cracks. We have not seen anything exactly like this structure before, and no definite explanation has up to the present suggested itself. Doubtless contraction on cooling together with lateral pressures and subsequent percolation of waters along the cracks to the kernels have done their share in its formation. In thin sections the slice splits up into a number of rounded and polygonal pieces, but no distinction is observable between those forming the kernels and those

forming the surrounding shells. The rock is a fine grained basalt composed of a felted mass of felspar microlites with minute grains of greenish augite, magnetite, and brownish-red olivines. The presence of any glassy material is doubtful. The texture is very fine and quite uniform, no phenocrysts having been met with.

All the basalts described so far bear a striking resemblance to each other, both in general characters and in mineralogical constitution. Their differences consist in the varying amount of glassy base and slight changes of texture, some having a few porphyritic constituents, and some being vesicular.

The small brownish-red grains of olivine form a peculiar feature common to all. Were it not for these olivines, the general characters of these lavas, and the fact that most of the felspars indicate a composition not lower in the series than labradorite, would suggest that they should be placed among the basaltic andesites. On the other hand the olivine is not present in sufficient quantity to make them olivine-basalts. In the absence of chemical analysis their exact classification is not ascertainable, and we have therefore left them with the somewhat indefinite designation of basalt.

Olivine Basalt, (No. 10).

A dark scoriaceous rock with numerous large olivines and black crystals of augite. Under the microscope the ground-mass is fine in texture, containing a number of very minute lath-shaped felspars. With higher magnifying power the base is seen to be glassy, slightly greenish-brown in colour, with numerous globulites and highly refracting grains. Intermediate in size between these and the felspars are numerous grains of pale brown augite, and also of brownish-yellow olivine. These olivines have a granular appearance. There are also many small magnetite grains.

Coming next to the porphyritic minerals we have:—Large crystals of magnetite. Large rounded grains of olivine, which are colourless but turning to a brownish-yellow along the cracks. Finally, very large crystals of augite. These have idiomorphic

contours, are frequently simply twinned and slightly pleochroic. The colour varies from a greenish-brown to a violet-brown in different crystals and frequently in the same crystal. Sometimes this change of colour takes the form of zoning, the kernels being greenish and the outer shell violet, and sometimes the two colours seem irregularly intergrown.

There are also a few corroded remnants of a brown hornblende. The original hornblende crystals are in several instances represented by remarkable pseudomorphs, similar in many points to those described in Basalt No. 5. There are, however, some features present in these which render a separate description desirable.

The ground-mass of these pseudomorphs consists of granules of almost colourless augite. These granules have in their interstices or intergrown with them little specks of colourless isotropic material, numerous elongated and branching patches of dark brown to opaque material similar to the fucoid-like inclusions described in No. 5, and finally many prismatic and granular pieces of brownish-yellow olivine similar to those in the base of the rock. A small piece of the original brown hornblende may or may not remain in the centre.

The augite framework, which appears to be in irregular granules owing to the number of these inclusions in it, is in reality optically continuous. In one case it is twinned, one half of the pseudomorph extinguishing at a different angle from the other. As no hornblende remains, it cannot be ascertained whether this twinning occured in the original mineral. Further, it appears from two of the pseudomorphs that this secondary augite has its plane of symmetry coincident with that of the hornblende. In one of these (*Plate* 13, fig. 5) which appears to be a section parallel to 010, the hornblende extinguishes at an angle of 16° with the vertical axis (shown by the prismatic cleavage), while the augite extinguishes at 43° on the opposide of the vertical axis. In the other case (*Plate* 13, fig. 6) we have a section approximately at right angles to the vertical axis as shown by the shapely defined

prismatic cleavages of the hornblende, and here the hornblende and augite extinguish simultaneously.

The dark brown to opaque inclusions do not occur in the original hornblende, but are confined to the surrounding altered portion. They do not appear to have any very definite arrangement, irregularly elongated and platy forms being common. On the edges, and when in thin films, they are translucent and of a dark brown colour. Associated with these are prisms and irregular patches of brownish-yellow olivine; and in some cases a layer of this olivine appears to fringe some of the brown inclusions, and one material seems even to pass gradually into the other (*Plate* 13 fig. 7.) It is a suggestion perhaps worth making that this dark material is a silicate of iron allied to ilvaite, which would resemble a fayalite in which some of the iron was peroxidised. The transition from this to a ferrugineous olivine, or vice versa, is easily conceivable.

Nos. 11 and 13 are fragments of basic scoriæ, varying from black to red in colour. Some are very highly vesicular and may be intermediate in composition. No. 11 is more compact and most of the vesicles are lined with zeolitic material.

Summary.

The collections submitted to us by Mr. Borchgrevink, in addition to proving the existence in Victoria Land of a group of trachyte lavas containing soda-augites, and other interesting rocks such as the ultra-basic limburgites and the mica-schist already described, appear to us to strongly confirm the conclusion already arrived at by Dr. Murray and several eminent biologists as to the existence within the Antarctic Circle of an Antarctic Continent rather than an Antarctic Archipelago. The schistose and granitic rocks collected by him at Cape Adare are distinctly of continental origin, and imply a strong probability of the continuity of Victoria Land with Adélie Land.

In speaking of Mr. Borchgrevink's work we can but echo the sentiments already expressed by Dr. Murray, that it is impossible

to overestimate its importance as bearing on the whole subject of the geography and geology of Antarctica ; and we here desire to express to him our warmest thanks for his courtesy in allowing us the privilege of examining and describing his collections. Our thanks are also due, for help kindly given us when preparing material for this paper, to the following :—Mr. H. S. W. Crummer, the Hon. Treasurer of the New South Wales Branch of the Royal Geographical Society of Australia; Mr. E. F. Pittman, Assoc. R.S.M., the Government Geologist ; Mr. G. W. Card, Assoc. R.S.M., Mineralogist ; Mr. W. S. Dun, Assistant Palæontologist and Librarian to the Geological Survey of N. S. Wales ; and to the following geological students of the University of Sydney:—Miss Montefiore, Miss Flavelle, Miss Haslam, Miss Noakes, Mr. H. J. S. Brook, and Mr. Graham Officer, B.Sc.

Explanation of Plates.

PLATE XIII.

Fig. 1. Triply-twinned grain of felspar showing Carlsbad, Mannebach and Albite types. Two of the sectors are shown extinguished.

Fig. 2*a*. Basal section of topaz, showing usual position of optic axes, the sign being positive.

Fig. 2*b*. Section of topaz, in *Granulitic Aplite*, A. No. 4, showing position of optic axes, the sign being negative.

Fig. 3. Prisms of rutile and anatase from *Granulitic Aplite*, A. No. 4.

Fig. 4. Crystal of olivine, from *Olivine Basalt*, A. No. 7, with intergrown meshwork of magnetite.

Figs. 5, 6. Pseudomorphs of hornblende composed of granular augite, colourless isotropic material, brownish-yellow olivines, and dark brown to black inclusions. These latter may be oxides of iron or possibly a silicate allied to ilvaite. Some of the hornblende remains in each.

The augite granules are optically continuous and have the plane of symmetry and vertical axis coincident with those of the horblende.

Fig. 7. A portion of Fig. 6 enlarged; the dotted grains represent olivines.

Fig. 8. Polished surface of basalt B. No. 8, at right angles to axes of ovoid lumps. The softer kernels of these lumps represented by lighter spots, from which irregular cracks radiate through the surrounding harder shells.

PLATE XIV.

Fig. 1. *Trachyte* A. No. 1 and 2, composed principally of sanidine and ægirine. A porphyritic crystal of ægirine is shown × 30.

Fig. 2. *Olivine Basalt* A. No. 3*a*, 3*b*, showing, near the centre, an arborescent grain of magnetite × 45.

Fig. 3. *Basaltic Andesite* A. No. 6, showing a large brown hornblende surrounded by a layer of opacite granules × 30.

Fig. 4. *Mica Schist* A. No. 5, section at right angles to plane of foliation × 30.

PLATE XV.

Fig. 1. *Basalt* B. No. 5, with large pseudomorph of hornblende. On the left of the centre a patch of the original mineral is seen × 20.

Fig. 2. *Basalt* B. No. 6, showing crystal of zoisite × 20.

Fig. 3. *Limburgite* A. No. 9, showing miarolitic structure, the cavities being filled with analcime. The dotted crystals are olivine. The glass is in dark brown angular patches or filled with fine granular augite × 30.

Fig. 4. *Limburgite*, A. No. 10, glassy base without the fine granular augite of No. 9. This is studded with a second generation of small augites and a few olivines. Two large porphyritic augites are shown × 30.

NOTES ON THE RAINFALL OF THE SOUTHERN RIVERINA 1872 TO 1894.

By HUGH CHARLES KIDDLE, F.R. Met. Soc.

[*Read before the Royal Society of N. S. Wales, December 4, 1895.*]

IN order to carry out an investigation of the rainfall of a large tract of territory, two essential conditions must be complied with, firstly, there must be a number of willing observers, well distributed throughout the district, and secondly, some one to undertake the task of collecting and digesting the records thus made available. I have undertaken the task of doing this for southern Riverina, and in the pages which follow I have endeavoured to

make this an exhaustive enquiry into the rainfall of the district lying between the Murray and the Murrumbidgee.

Out of one hundred and twenty-five stations herein discussed, the Government Astronomer has furnished me with the particulars of seventy-three stations; for the remaining fifty-two I am indebted to the proprietors of these stations who very kindly responded to my request for copies of their records.

I.—Area under consideration.
II.—Divisions.
III.—Tables.
IV.—Summary.

(I.) The district which, for the purpose of this paper, is termed the Southern Riverina, embraces all the area between the Murray and Murrumbidgee Rivers, and extending as far east as the meridian of 147° 30′. The locality to the eastward of that meridian is termed the western slopes of the southern table-land. The records of the town of Albury, situated in the extreme south-east of this area, have been omitted. The reason for doing this is that the township is surrounded by hills, a fact, which, in my opinion, considerably affects the rainfall. I mention this to show that only stations which may be said to belong to the Southern Riverina have been selected, and that the results are not simply a large collection of statistics irrespective of locality. As Albury has a very long and valuable rainfall record, you might be sure that there was a valid reason for omitting it. The area of the district is approximately 19,700 square miles, or embracing about twelve and a half millions of acres of the finest wool and wheat growing lands of New South Wales. The length is about two hundred and thirty miles, and average width about eighty-four miles. The surface may be characterised as a generally sloping plain falling from east to west. The altitudes on the eastern side are given thus for Wagga Wagga 615 feet, Albury 530 feet, the level at Deniliquin is 320 feet, while at Balranald about 230 feet, being a fall of about two feet per mile for the first interval and one foot per mile for the second.

(II.) *Divisions.*—The area has been divided into four sections, the dividing lines being the meridians of longitude. They are designated—

Section.	From.	To.
A	Junction of Rivers Murray and Murrumbidgee.	145° E.
B	145° E.	146° E.
C	146° E.	147° E.
D	147° E.	147° 30′ E.

This method of division was selected as it was found to be more workable than taking the square degree or other arbitrary unit, and it also conformed to the *geographical nature* of the district. The first three sections are essentially part of the Southern Riverina, but Section D encroaches somewhat on the southern tableland. For this reason only those stations situated on the northern, central, and western sides were used for the purpose of computing the Table No. 4.

(III.) The Tables numbered 1, 2, 3, 4, have been compiled for each year by taking the sum of the available rain records for each month in that year and dividing by the number of stations. I may say that the stations are well distributed throughout each section, so that the average for each year, although the result of a constantly increasing number of stations, is a very true one.

One pleasing feature is the large number of stations representing Section A. I have obtained twenty-nine records for 1893 for this section. In all sections where there are two or more reports from the same place, either only *one* of them, or else the average of the two has been counted in the mean. For instance Wagga Wagga has two records, both dating from 1873. In such a case I take the mean of the two records and call it *one* station. The reason is obvious, for the results would otherwise probably be misleading.

Table (1) gives monthly and annual results for all stations in Section A. Table (2) same for Section B. Table (3) same for Section C. Table (4) same for Section D.

TABLE I.—Results of Monthly and Annual Rainfall, 1872 to 1894, for Section A.—Balranald to Long. 145° E.

Year.	No. of Stations.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1872	3	·37	·07	·50	·43	·92	4·05	1·31	1·24	1·35	1·93	3·28	1·27	16·72
1873	3	5·01	3·16	·10	2·29	1·40	1·29	·82	2·69	1·92	·88	·88	·65	21·59
1874	3	3·34	—	4·31	1·33	1·36	1·67	·63	·51	2·29	·50	·31	·12	16·37
1875	4	·16	2·04	·78	1·71	2·97	3·13	1·20	2·44	1·01	1·81	·57	1·37	19·19
1876	5	·65	·51	1·68	·16	2·91	·16	·10	2·07	1·01	1·31	3·77	·22	14·55
1877	9	·50	1·05	2·35	·46	1·85	1·21	·63	·12	2·62	·63	·35	·37	12·14
1878	11	—	4·53	5·96	1·83	·25	·99	2·42	·44	·61	1·77	·67	—	19·47
1879	14	21	·34	·72	1·32	1·29	·80	1·04	1·61	1·29	2·81	1·60	·60	13·64
1880	14	·61	2·36	1·48	2·87	·48	·76	·31	·54	1·41	·59	·38	·31	12·10
1881	18	1·10	1·68	1·96	·23	2·05	1·61	·40	1·18	1·57	·73	·75	·45	13·71
1882	20	·02	·02	·09	2·83	1·00	·88	1·04	1·79	0·29	2·29	2·46	·97	13·68
1883	20	·01	·66	1·67	·73	1·77	1·20	·53	1·42	1·80	1·31	·87	·30	12·27
1884	20	·31	·28	1·15	·49	1·74	1·46	·04	·53	1·06	·73	1·34	·21	9·34
1885	22	·35	1·82	·82	1·73	·59	1·41	·92	·74	2·32	·68	·17	2·08	13·63
1886	23	1·39	·06	·25	·08	1·09	·68	1·73	2·86	1·63	1·11	·57	2·57	14·02
1887	24	·26	2·38	1·47	2·21	1·09	2·63	1·61	1·36	·95	1·95	4·19	1·88	21·98
1888	27	·43	·62	·32	·41	1·77	·59	·42	·54	·98	·22	·26	·76	7·32
1889	26	2·16	2·95	—	3·73	4·12	2·11	·27	3·02	1·71	1·39	1·99	·06	23·51
1890	27	·05	·33	2·89	·76	2·18	2·69	2·62	1·46	·59	1·75	1·58	·71	17·61
1891	26	2·38	—	1·22	3·30	·88	1·77	1·52	1·99	·65	1·72	1·17	·29	16·89
1892	28	·10	·20	·23	·66	2·86	·79	1·45	1·72	1·45	3·08	1·36	·25	14·18
1893	29	·05	·01	·52	·90	3·24	1·38	·99	1·23	1·49	·78	1·89	·40	12·88
1894	26	·59	·24	2·72	1·45	·98	2·90	1·31	1·95	·88	3·52	·35	4·32	21·21
Mean of	23	years ..			...	...	...	..	...	...	...	...	...	15·56

TABLE II.—Results of Monthly and Annual Rainfall, 1872 to 1894, for Section B.—Longitude 145° E. to Longitude 146° E.

Year.	No. of Stations.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Total.
1872	3	·24	·28	·41	·52	1·63	4·71	1·46	1·44	1·75	2·81	3·32	·58	19·15
1873	3	5·26	3·02	·50	1·96	1·11	1·30	·50	2·27	1·56	·72	·79	·56	19·55
1874	4	2·22	—	3·09	1·47	1·71	1·95	·98	·87	2·31	·38	·02	·04	15·04
1875	5	·39	3·16	·61	1·70	3·07	4·73	2·02	2·56	1·30	1·27	·95	1·48	23·25
1876	5	·24	·79	1·49	·02	2·86	·25	·22	1·81	·87	·60	3·08	·37	12·60
1877	8	·63	·60	·81	·23	1·67	1·67	·97	·23	2·83	·49	·56	·57	11·24
1878	9	·04	5·92	4·44	1·31	·40	1·26	2·42	·79	1·93	2·65	1·47	·02	22·65
1879	12	·46	1·37	·73	2·41	·97	·76	1·56	1·56	1·46	2·87	1·66	·47	16·27
1880	14	·65	2·00	1·95	4·14	1·06	1·06	·58	·57	1·73	·92	·21	·28	15·15
1881	14	·33	2·09	4·09	·10	1·92	1·74	·45	1·06	1·45	·84	1·03	·56	15·66
1882	17	·16	·03	·10	3·12	1·59	·88	·98	2·33	·24	2·78	2·07	1·32	15·60
1883	17	·02	1·01	1·15	·62	1·96	1·56	·68	1·49	1·64	1·92	·94	·26	13·25
1884	18	·52	·42	1·03	1·12	1·41	2·26	·24	1·13	1·08	1·56	1·37	·50	12·64
1885	17	1·62	1·13	·62	2·78	·61	1·59	·81	·60	2·66	1·35	·27	1·76	15·80
1886	19	1·45	·21	.31	·15	·89	·87	1·48	3·36	1·50	1·39	·65	2·36	14·62
1887	20	·69	3·25	3·48	1·63	1·65	2·45	1·79	1·63	1·06	2·31	3 88	2·19	26·01
1888	20	·74	1·01	·28	·36	2·44	·62	·52	·63	1·18	·29	·50	1·04	9·61
1889	21	2·52	3·10	·01	3·67	5·15	3·06	·39	3 68	1·95	1·62	1·88	·28	27·31
1890	22	·05	·32	2·71	1·04	1·95	3·27	2·51	1·35	1·09	1·70	1·45	·72	18·16
1891	22	3·31	·05	2 02	3 57	1·17	2·68	2·59	1·80	1·25	1·38	1·28	·36	21·46
1892	24	·53	·19	·07	·85	2·97	·91	1·64	2·64	1·48	3 36	1·86	·28	16·78
1893	26	·04	·03	·92	1·29	3·40	1·70	1·02	1·53	1·76	1·14	1 75	·78	15·36
1894	24	·68	·48	3·42	2·30	1·89	3·70	1·82	1·78	·88	3·71	·31	2·83	23·80
Mean of	23	years...			...	..	...	...	...	...	...	...	...	17·43

TABLE III.—Results of Monthly and Annual Rainfall, 1872 to 1894, for Section C.—Longitude 146° E. to Longitude 147° E.

Year.	No. of Stations.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1872	2	1·00	·86	1·20	·12	3·36	6·10	2·53	·82	1·70	4·35	3·19	2·07	27·30
1873	2	3·82	2·80	·05	2·27	·91	3·10	·42	2·48	1·12	·73	·62	·29	18·61
1874	2	2·42	—	4·25	·80	3·09	2·00	1·06	1·45	2·75	·48	—	—	18·30
1875	3	·10	3·76	1·43	2·81	3·64	4·41	2·01	3·13	1·39	1·53	1·48	2·24	27·93
1876	5	·08	·65	1·35	·07	3·18	·36	·10	1·76	1·54	1·37	2·28	·41	13·15
1877	6	·77	·97	1·03	·59	1·88	2·20	1·05	·27	2·84	1·16	·83	1·07	14·66
1878	6	—	3·99	4·19	1·84	·44	1·91	2·69	·99	3·08	3·63	2·19	·03	24·98
1879	8	·47	1·71	1·38	2·59	1·53	·81	2·18	1·86	1·68	3·40	2·03	·70	20·34
1880	12	·75	1·80	2·12	4·67	1·48	1·58	·45	·74	1·77	1·54	·44	·38	17·72
1881	13	·43	2·33	3·85	·33	2·05	1·77	·48	1·15	1·40	1·05	1·18	·85	16·87
1882	18	·32	·17	·37	3·49	2·39	·78	1·16	2·69	·28	3·67	2·23	1·28	18·83
1883	21	·01	1·06	1·57	·79	1·65	1·91	1·10	1·55	1·58	2·84	1·17	·36	15·59
1884	26	·35	·54	1·08	·73	1·48	1·57	·10	·65	·98	·99	1·54	·42	10·43
1885	32	2·26	1·64	·57	1·67	·70	2·20	·59	·90	3·17	1·34	·96	1·61	17·61
1886	36	1·44	·30	·34	·40	·92	1·02	1·74	4·03	1·76	2·73	1·16	2·70	18·64
1887	41	·94	4·12	4·27	1·26	1·80	3·03	2·64	1·74	1·20	2·78	3·47	2·00	29·25
1888	43	1·10	2·19	·23	·30	2·62	·96	1·02	·86	1·00	·39	·69	1·82	13·18
1889	44	2·49	2·95	·02	2·79	5·77	3·60	·82	3·33	2·31	1·81	2·58	·60	29·07
1890	44	·09	1·36	2·74	1·04	2·58	3·04	2·45	1·42	1·65	2·04	1·64	1·44	21·49
1891	43	4·40	·11	1·97	3·16	1·24	3·23	4·06	1·58	1·34	1·42	2·19	·49	25·19
1892	43	1·54	·22	·19	1·71	2·55	1·08	1·78	3·05	1·97	2·63	2·68	·65	20·05
1893	44	·19	—	1·66	1·84	4·19	2·08	1·68	1·98	2·31	1·87	2·54	2·23	22·57
1894	44	1·09	1·02	3·82	3·50	2·26	3·83	2·72	2·22	1·40	4·00	·47	2·53	28·86
Mean of	23	years...		...	...	...	...	...	...	...	...	...	...	20·46

TABLE IV.—Results of Monthly and Annual Rainfall, 1872 to 1894, for Section D.—Longitude 147° E. to Longitude 147° 30 E.

Year.	No. of Stations.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1872	1	1·66	1·53	2·87	·02	2·94	6·62	1·81	1·71	2·09	3·51	3·17	2·11	30·04
1873	1	3·18	1·27	—	2·65	·77	3·54	1·12	1·54	1·70	1·09	2·73	·76	20·35
1874	1	4·10	·55	4·88	2·75	2·39	3·05	3·10	2·85	3·80	1·65	·15	—	29·27
1875	1	1·22	3·20	·57	3·20	3·20	3·86	1·44	1·93	1·76	1·68	2·05	2·15	26·26
1876	2	·27	·89	1·52	—	3·62	·55	·79	2·45	1·38	1·35	2·83	·59	16·24
1877	2	1·04	·57	1·37	1·68	2·55	3·05	1·01	·55	2·80	1·33	·45	2·97	19·37
1878	2	·03	3·81	3·33	1·84	·35	3·00	3·02	1·07	2·54	4·02	2·21	·22	25·44
1879	3	·60	1·87	2·45	2·77	2·71	1·05	2·54	2·48	2·64	2·33	2·75	·43	24·02
1880	2	·82	2·26	1·77	4·00	1·54	1·81	·69	1·04	1·04	2·11	·41	·99	18·48
1881	3	·40	2·43	2·91	·55	2·55	2·60	·73	1·16	1·46	1·43	1·65	1·05	18·72
1882	4	·70	·63	·83	3·65	2·94	1·51	1·77	3·71	·50	3·38	3·32	1·56	24·50
1883	5	·05	1·41	1·98	·76	1·63	1·78	1·39	1·67	2·28	3·81	1·41	·34	18·51
1884	7	·45	·49	1·29	1·52	1·13	3·64	·52	1·46	1·12	2·00	1·52	·81	15·95
1885	9	3·59	2·60	·44	1·08	·69	2·98	·56	1·18	3·12	1·43	1·53	1·33	20·53
1886	11	1·43	·52	·47	·61	1·21	1·01	2·08	4·94	2·25	3·89	1·63	2·36	22·40
1887	11	1·26	4·58	5·39	·59	1·44	3·77	3·33	2·05	1·56	2·90	2·60	2·95	32·42
1888	12	·92	2·85	·52	·15	2·13	1·72	1·70	·72	1·48	·33	·71	2·42	15·66
1889	12	2·70	2·72	—	2·78	6·09	4·48	1·23	3·39	2·62	2·21	3·38	1·11	32·71
1890	14	·21	2·17	3·55	1·27	2·96	3·83	3·12	1·77	2·23	2·55	2·05	2·02	27·73
1891	15	5·80	·14	1·85	3·01	1·22	4·62	5·20	1·77	1·66	1·68	2·89	·59	30·45
1892	15	2·08	·28	·78	2·05	2·79	1·49	2·09	3·88	2·48	2·48	3·14	·55	24·09
1893	17	·27	—	1·41	2·00	3·91	3·71	2·64	2·28	2·50	2·51	3·04	3·33	27·60
1894	13	2·09	1·47	4·32	4·30	1·74	4·45	3·78	3·14	1·88	4·66	·66	2·87	35·36
Mean of	23	years...		...	...		...	...	...	...	...	...	...	24·21

(IV.) *Summary.*—In dealing with a subject so uncertain as rainfall, the most important feature to be discovered is its periodicity. In fact I think that this is the only point of importance in connection therewith.

The question of periodicity has been dealt with by many writers, and the number of different theories advanced is somewhat perplexing. There are periods of three, five, eleven, nineteen and thirty-three years; all of these have their supporters. In many instances an agreement exists between one of these periods and the figures representing the rainfall, and this agreement is immediately set forth as a positive theory. As it is orthodox to assume that rainfall is governed by certain laws, more or less proven, argument on the matter is out of place in these notes. Suffice it to say that I do not consider that the records of twenty-three years which I have now set before you, show definitely any periodicity, for the simple reason that I do not think the observations cover a sufficiently long series of years to actually prove anything. I beg to draw your attention though to the fact that the amounts of the annual totals coincide closely and conform to the period set down as a nineteen year cycle. By taking the monthly values I find that the period shows eighteen years two months. For instance, the dry period commencing in October 1874, and lasting for four months is repeated in December 1892, when a dry period of three months set in.

The annual results agreeably conform to the nineteen year cycle as shown by the following examples:—1875, 1894, and the three years immediately preceding these years respectively. These are, what may be called all good years or years of a plentiful rainfall. Unfortunately our series for this district does not give us an opportunity of comparing the recurrence of the dry years.

I think I am correct in stating that the nineteen year period originated with our Government Astronomer Mr. H. C. Russell, F.R.S. I mention this to show the excellence of the authority I quote when applying the cycle to this discussion.

The periodicity may therefore be summed up as indicative of a recurrence of similar seasons at intervals of about eighteen or nineteen years. Taken alone this knowledge may prove of much service to both the pastoralist and the agriculturalist, and if so, one of the objects aimed at will have been accomplished. But apart from the knowledge of the periodicity, these tables afford the means of working out the relationship between the amount of rainfall and the resulting crops. This may be effected by comparing the amount registered in any particular season, that is from ploughing time to harvest of any particular year, with the recorded average yield per acre of the crop under consideration. For instance bushels per acre would be assumed in discussing wheat crops, tons per acre if vines.

The tables are particularly useful in this respect, as by dividing the period the crop is in the ground into sections, the most beneficial amount of rainfall and opportune season for it to fall may be discovered. A wheat crop for instance, may be divided into (1) ploughing and sowing period, (2) growing period and (3) ripening period. The fact that the same annual amount of rainfall will not necessarily produce the same result in the crops in any two years is so apparent as to need no enlargement thereon.

In conclusion I may say that although the period of twenty-three years is short from a meteorological point of view, the results deduced therefrom will I hope be found not altogether unworthy of notice.

At some future period I hope to be in a position to place before you not only the rainfall results of this district, but results of the investigation of rainfall, pressure, temperature, winds, etc., combined, and not only for this district but also for any other in which it may be my lot to reside.

Finally, before I close my remarks, I must take the opportunity of thanking all those gentlemen who have supplied me with copies of their records; without their assistance this paper could not have been produced. I must also thank the Government Astronomer,

Mr. H. C. Russell, F.R.S., for his kindness in supplying nearly two-thirds of the data to me, more especially for the year 1894, for by his kind assistance in that direction I have been enabled to bring the subject matter up to date, and thus render it more interesting, and I hope useful.

THE GREAT METEOR OF MAY 7TH, 1895.

By H. C. RUSSELL, B.A., C.M.G. F.R.S.

[*Read before the Royal Society of N. S. Wales, July 3, 1895.*]

FROM time to time we get reports of earthquakes on the western plains, and various circumstances connected with them convinced me that they, or at least some of them, result from meteoric explosions, and I have at last obtained what seems to me to be clear and definite proof that what was accepted by a large number of persons as an earthquake, was simply a vibration in the earth, caused by a terrific explosion overhead. Some of the observers, indeed describe it as like the explosion of a magazine. Sturt was once startled at 3 o'clock in the day (Feb. 7, 1829) when on the Darling, by a great explosion "like the discharge of a heavy piece of ordnance five or six miles away," and in the early days, 1789 (17 Jan.), all Sydney was agitated by what was supposed to be the explosion of a gun outside the heads, and everyone who could get a horse or a gig went off to South Head with all speed, to see the ship, but no ship was in sight, anxiously as she was looked for.

The source of the great explosion this year was fortunately observed by a great number of persons under conditions which clearly point to the explosion of a meteor as the cause of the noise and the earthquake. The first intimation I received of it was a telegram from Mr. Thomas Cadell, who happened to be at

Bedooba Station, some sixty miles south of Cobar, and while sitting at a table reading, distinctly heard the glasses rattle together as a rumbling noise passed the house. Many others in Nymagee and Gilgunnia had a similar experience. Later Mr. Cadell got reports from the Cobar mailman that at the time he had seen a great meteor pass over, and from Mr. Edgar who was startled out of his sleep by the noise, and thought he saw the moon falling; these reports pointed clearly to the cause of the earthquake, and I wrote to the daily papers asking for information. Thanks to many correspondents to whom I am indebted for valuable reports, I have now been able to trace the meteor over this colony so well that I think it ought to be placed upon record. I have never before heard of such a magnificent meteor in Australia, and it is not often that any part of the world is visited by such a fine one. Unfortunately no one has referred its path to the stars: if they had, it would give us more exact information of its path in the heavens, and there are still some points to clear up which the publication of what follows may bring out, at least it will place upon record all that I have been able to learn of this truly magnificent meteor, and show that at its explosion a distinct tremor of the earth was experienced in the houses near.

No. 1, *Nyngan*—Mr. C. Maclean reports to Mr. Edwin Lowe of Wilgar Downs, that he was camped at Nyngan with sheep, he was on watch about 11 p.m., when a gigantic meteor passed over head travelling about due south-west, the ball of fire was twice the size of the moon and had a long train after it, travelled slowly and was in sight for several minutes. At Wilgar Downs a brilliant light was seen by Mr. Lowe junior after he had retired, but at the time he did not know what it was.

No. 2, *Nymagee*.—Mr. G. Robinson was on the night of May 7, on his way from Nymagee to Gilgunnia, at a point marked by a cross on the map. At the moment he was driving due west, "when suddenly and without any warning a dazzling patch of light about twenty feet in diameter appeared on the ground just to the right of the horses' heads; the horses

instantly shied from the light and turned their heads to S.W. and we saw the meteor before us. The most beautiful sight was the reflection of the light from the ground, it seemed at one moment to burst off in all directions giving out magnificent colours; I was surprised at its being confined to such a small space, a circle as just stated, not more than twenty feet in diameter. Its brilliance was very remarkable and affected or rather dazzled our eyes; this may account for the meteor not appearing so bright to us afterwards. The ground where the light struck was bare and dry, trees formed a good back ground for the light, but they were some distance away, and the light lasted about eleven seconds. When this brilliant light struck the ground, it seemed to ascend from the ground again, splashing up over our heads and leaving the spot in darkness: at the same moment I noticed a chain of light dart from this spot, flying along the ground first south, then it darted across our track, and immediately darted back east passing back on our left and close to us. I knew that this light was given out by some brilliant object high up behind me, and I expected to see something when I turned my head suddenly over my left shoulder. I was surprised to see the meteor

coming away from north-east; it was high up but falling towards us; at first the tail appeared about 1½° long and inclined upwards, but as it passed by on the east side of us it seemed to be 10° or 12° long; it changed colour at first, but I saw no sparks in it. The object in front (*i.e.*, the meteor) seemed to be 3½ to 4° ahead of the flash or tail of smoke, this distance got greater when close to us. When opposite to us the motion was too rapid for such observations, although I could see the trail quite distinctly: it looked like sheet lightning, and it disappeared when the meteor was due south of us."

"As the meteor passed us the trees under it actually glittered with its light, while east and west of the track the tree tops appeared dark. The meteor passed to the east of us as just stated, but almost over our heads from north-east to south-west. The hissing noise as it passed was something like the flare noise of a gas jet, but very much louder. The remarkable brilliance of the light which dazzled our horses may have affected our eyes, and this would account for the fact that the meteor itself did not appear so bright. The tail looked like a tongue of flame gliding along after a dark object two degrees in diameter, which seemed to be enveloped in smoke." [Probably the meteor looked dark because (1) they were looking at the back of it, and (2) the front of the meteor would be the great point of heat and light in its passage through the atmosphere.] "Subsequently he heard three loud reports as if three heavy guns had been discharged almost at the same moment and quite near them."

When they reached Gulgunnia the townspeople were found to be in a state of alarm at what they thought was an earthquake. They said the noise was like heavy thunder that rolled past from the north-east. At Nymagee the noise of the explosion was so great and the earthquake so severe that almost every person in the town was alarmed. Mr. Robinson gives the time 10 h. 30 m. as that at which the meteor passed, but his watch must have been fifteen or twenty minutes slow, for Mr. Cadell at Bedooba, sixty miles away, made the time 10 h. 50 m., and the three observers

at Rookwood fix the time by railway clocks at 10·48 p.m. or within a minute or two of that.

No. 3, *Bedooba.*—Mr. Thomas Cadell of Hillston, was at Bedooba on May 7, and at 10·50 p m. felt a very distinct earth tremor pass the house from south-west to north-east, the noise lasted about two minutes; it very much resembled the noise made by an iron tank being rolled rapidly over a rocky place, and he heard it gradually dying out in the distance. He also distinctly heard the glasses in the house rattling together and the kerosene lamp on the table at which he was reading decidedly tilted and momentarily flared up just as the rumbling noise passed the house. Mr. Edgar, who was camped about fifteen miles south-east from Mount Hope, reported to Mr. Thomas Cadell that he was asleep when the noise of the meteor awakened him, and looking up he saw a bright body passing overhead, and for a moment he thought it was the moon that was falling, it was so large. It had a tail of smoke and flame apparently twenty yards long, and the light it gave completely snuffed out the moon which was near the full. The mail driver from Mount Hope northwards reported to Mr. Thomas Cadell that he had seen an enormous meteor travelling horizontally from north-east to south-west, and it disappeared about 10·15 p.m.: about five minutes after the meteor passed he heard a rumbling noise travelling from south-west to north-east, and he thought the noise was made by the meteor exploding.

No. 4, *Orange.*—Mr. District Surveyor Crouch was driving in a hooded buggy home to Orange, and at about 10·15 p.m. of May 7th saw the meteor, his attention being attracted by a bright light: he looked out and just saw for a fraction of a second the meteor travelling from north to south about 5 or 7 degrees above the horizon. The size appeared about half the diameter of the full moon. He did not hear any noise, nor was the trail particularly noticeable. "It was certainly the largest meteor I have ever seen, its bearing was about west by north."

No. 5, *Bathurst.*—Miss Gilkrest, Bathurst, saw the meteor of May 7th at 10 h. 50 m. p.m., and thought the moon was falling, so

large and brilliant was the meteor. The meteor seemed to travel from north to west leaving a trail of light behind it for some time; it appeared to descend to the ground at an angle of about 45°. It was so brilliant that its light shining through the window blind attracted attention, and it moved so slowly that there was time to pull up the blind and see the meteor.

No. 6.—Mr. J. Smethurst of *Wyalong*, was walking towards the south about 11 p.m. on May 7th, the moon being nearly full, "when suddenly the bright moonlight was absorbed by a brilliant light behind me; on turning round I saw a meteor about the same diameter as the moon, it was due north of me then, and 15 or 20° above the horizon. The meteor presented the usual train of light &c., but it did not burst, it remained visible six or seven seconds. towards the end of its path it grew gradually fainter and finally went out without reaching the horizon." Mr. Hunter, a friend, confirms these statements as to its brilliance, direction, and not reaching the horizon, but thinks it was only a quarter the size of the moon.

No. 7, *Minto*—Mr. T. P. Latta saw the meteor of May 7th at 10·50 p.m., it travelled at a great pace from north to west, it seemed to disappear behind the Minto hills. The night was beautifully clear, "when I saw a magnificent meteor, its head like a ball of electric light and the tail seemed to give out prismatic colours like a rainbow. The head seemed to be two thirds of the diameter of the moon and the tail half the moon's diameter in width, and its length ten or twelve times the diameter of the moon. The tail of the meteor seemed to give out colours something like the flashing of a diamond in the sun; compared with all the meteors I have seen before, this was a giant."

No. 8, *Rookwood.*—Mr. Richard Peek saw the meteor on May 7th at 10·48 p.m., it came out of a small dark cloud more than half-way up the sky *(visual angle* 30°, *half-way up probably* 15°) it was very brilliant, like a ball of fire as large as the moon, and it had flames shooting out from it on all sides fully half the moon's

diameter long; its course was marked by a trail like sparks of fire, fully three degrees long; it was in sight for fully half a minute. Its light, like sunlight, made every other light pale, only it looked like a ball of iron at a white heat. It left a trail behind it two or three degrees long and one degree wide. It travelled in a curve and very slowly.

No. 9, *Rookwood*—Mr. Bissett, Post Master, Rookwood. "Mr. Peek called my attention to the meteor, time 10·48 p.m. It was a magnificent object, moving slowly, and remaining in sight twenty to twenty-five seconds; it was as large as the moon and as brilliant as the electric light, I took the time from Mr. Morton, whose watch was adjusted to railway time. Messrs. Peek, Morton, and I were standing together and saw it, in all important points we are agreed, except that our estimates of the time it was visible differ a little, it lasted twenty to twenty-five seconds by my estimate.

No. 10, *Rookwood.*—Mr. Peter McGrath of Mary Street, Rookwood, on May 29th, in course of conversation said he saw the meteor of May 7th; he did not look at a watch, but the trains ran always within a minute of true time, and he took the time when he saw the meteor to be 10·46 p.m., because one train left the station at 10·39 p.m. and another at 10·52 p.m.. The meteor seemed to come out of a cloud which was about 12°, above the horizon, and immediately afterwards fire seemed to flash out of it all round as if it exploded, and its size increased enormously. From this explosion an intensely brilliant meteor seemed to shoot out and go away to the south. When first seen it was over a hill which he believes to be Tomah, bearing W.N.W. The moon was near the full and shining brightly, and he is sure the meteor after the explosion was three times the diameter of the moon.

No. 11, *Strathfield.*—Mr. H. S. Thompson, Architect and Surveyor, saw the meteor of May 7th. He was standing on the Strathfield Railway Station and saw the meteor at 10·50 p.m., it was exceedingly brilliant; it seemed to descend, then suddenly expand in size and brilliance and shoot away more brilliant than

before. The sudden increase in brilliance occurred apparently over Mount Tomah, two or three degrees above the top of that hill. The light was dazzling and cast strong shadows.

No. 12, *Ashfield.*—Mr. Ernest A. Nichol, at Ashfield with a friend; "we both saw it begin at 12° above horizon; it was at first a bright yellow, then dull gold, and at 8° high it burst out into a brilliant whitish light like an explosion, but no sound was heard, thence it was nearly parallel to the horizon. It appeared to be due west when it went out. In the latter part of its course it assumed a long fish-shape and emitted a dazzling light, like the electric light: head and tail together during this part of its course had a form like an indian club used for calisthenics, the handle end flattened a little."

No. 13, *Kiama.*—Capt. H. H. Honey of Riversdale, had a fine view of the meteor of May 7th, about 11 p.m. It was the most brilliant meteor he had ever seen. At first it appeared as large as Venus but much more brilliant, and gradually grew larger until it appeared about twice the size of the moon, which was shining brightly at the time: its track was towards south-west by south, and its motion much slower than that of ordinary meteors. He first saw it north-west 5° N., and the great explosion took place exactly west-north-west; this was ascertained, first by noting the exact place of observation, then the relation of the apparent position of the meteor to certain trees on the neighbouring hills, and then returning to the place and measuring the bearings with an azimuth compass, and the elevations by the same means. When first seen at north-west 5° N. its elevation was from 20° to 23°, say 21°, it was then following a slowly descending course, and after the explosion it seemed to descend more rapidly and disappeared below the horizon at a point 5° south of west over a range of mountains 2,000 feet high, with an elevation of 4° as seen from Kiama. The meteor was of extraordinary brilliance, so much so that although the moon was nearly full and shining brightly, the shadows cast by the meteor were quite distinct. At its greatest the meteor looked twice the size of the

moon. "The most peculiar circumstance I noticed was that during its flight its speed seemed to be suddenly checked, and its course changed considerably, and the meteor suddenly burst into brilliance, lighting up the surrounding heavens in a scene of indescribable grandeur. No word picture that I have ever seen painted could adequately describe it. I have witnessed many wonderful and beautiful views in the heavens, but the grandest pales into insignificance when compared with this: the light was so brilliant, yet not dazzling, and as if all the most beautiful colours the mind can imagine, blended into an indescribable one, which filled the whole heavens, from a point south-south-west to a little north of west, the sight was such as I can never forget. I was riding a somewhat spirited horse at the time and he suddenly stood still and trembled. The peculiar light died out gradually, but remained visible long after the meteor itself had disappeared. I listened attentively for any sound and heard none until about thirty minutes after I saw the explosion, and then heard a low distant rumbling, which suddenly became louder as if heavy artillery was heard at a distance." In reply to my question, he was sure the explosion took place at a point (by compass) west-north-west, and is quite sure that its altitude when first seen was between 20° and 23°.

No. 14.—Mr. Waite who resides fourteen miles south of *Coolo-lalin*, saw the meteor, and distinctly heard a rumbling noise directly after seeing the meteor, and he thought the noise lasted half a minute.

No. 15, *Shellharbour*.—Mr. Frank James of Shellharbour, and two other persons, saw the meteor a few minutes before 11 p.m. It appeared near the horizon, between west and north west and had a bright tail of flame; it seemed to disappear behind the Illawarra Range of mountains.

No. 16, *Dine Dine*.—Mr. H. C. Wade of Dine Dine Station, saw the meteor about 11 o'clock on May 7th. He heard very loud noise much like thunder only much louder, which lasted for a considerable number of seconds, and upon going outside to see

what it was, he saw a very large body of fire which started in the west and travelled right across the sky. The ball of fire seemed to be about five diameters of the moon across, and as it travelled it sent out long tongues of flame. The night was very clear and no wind until after the meteor passed, when there were a few strong puffs.

No. 17, *Springwood.*—Mr. Hector Rayner of Springwood was riding a bicycle from the Valley towards Springwood on May 7th "when suddenly there was a brilliant light which made me think the end of the world was come." When he looked up the meteor was passing from north to west, but it seemed to fall and go behind the hills before it reached the west; it was moving slowly compared with small meteors and its size did not diminish. When about north-west it threw out lovely blue lights, and after it went behind the hills the sky was perfectly red; it seemed to disappear behind Mount Hay, which lies west-north-west from here. The colours were like beautiful rocket colours which seemed to follow it as if it were a rocket. It appeared to be far larger than the stars.

No. 18, *Cockringe.*—Mr. George Cadell of Cockringe, Mudgee, was talking to a person in the road on 7th of May, a few minutes after 11 p.m., they were both attracted by a brilliant light in the sky, and looking up saw an immense ball of fire shooting across the sky from north to west; he said it was the most wonderful thing he had ever witnessed, the light being so brilliant, he could have read the smallest print. Mudgee is one hundred and ninety miles east of the meteor's track.

No. 19, *Sutherland.*—Mr. E. Lewis of Sutherland saw the meteor of May 7th at 10·50 p.m. in the north-west. It was rather low down and near the horizon and very brilliant while it lasted. It gave off a number of sparks in the first part of its course and seemed to descend as a large mass of fire; he lost sight of it behind the mountains.

No. 20, *Condobolin.*—At Melrose Station, near Condobolin, about 11 p.m. May 7th, a large and brilliant meteor was seen by some dog-trappers on this station. A rumbling noise was heard.

No. 21, *Murrumburrah*.—At Murrumburrah, one of the most southern points of observation, Mrs. Aiken states that on the night of May 7th her sons were out shooting, and between 10 and 11 p.m. were surprised to see what they took to be a great comet moving from north to west.

No. 22, *Wyalong*.—Mr. H. J. Naylor of Wyalong saw the meteor on May 7th; he was walking from Wyalong West to Wyalong, *i.e.*, towards the east, and at a few minutes after 11 p.m. his attention was attracted by a bright light and a buzzing noise, and turning to the left saw a ball of fire as large as a foot ball approaching him from the north at a great rate, and leaving a long train of sparks behind it. At first it appeared to be very high but falling, when it seemed to be within two hundred yards it looked not more than fifty feet high, but its light died out before it reached the earth.

No. 23, *Terangan*.—Mr. A. A. MacInnes of Terangan Station. "On the evening of May 7th I heard a loud report similar to the explosion of a magazine, the noise came from a westerly direction."

No. 24, *Cugong*.—Mr. Hudson C. Shaw of Cugong, saw the meteor at about 11 p.m., May 7, 1895. It seemed to rise from the northern horizon and travel swiftly towards the west. Estimated the time of passage as two minutes. The light was vivid, throwing strong shadows of trees in the bright moonlight. Twenty minutes after the meteor, he heard a faint rumbling noise like distant thunder seemed to come from the north. (Meteor's track was about ninety miles away from Cugong.)

No. 25, *Meryula*.—A very brilliant meteor passed over Meryula Station at about 10·30 p.m., May 7, 1895. It seemed to be quite as large as the moon and was visible for a minute.

No. 26, *Lake Bathurst*.—Mr. Badgery of Lake Bathurst saw the fine meteor of May 7th, about 10·50 p.m. It was seen first in the north, and it travelled thence slowly towards the west, leaving a long trail of fire behind it which remained visible for some time.

As stated at the beginning of these notes, my chief object was to show that earthquakes felt on our western plains were sometimes if not always caused by the explosion of large meteors, and I think that the reports show clearly that in this instance a great explosion in the meteor was coincident with the earthquake, and further that the explosion was seen to occur at a point directly over that part of the country where the earthquake was sufficiently severe to alarm some hundreds of people. Capt. Honey's observed bearing of the explosion, places it almost exactly vertically over Mr. Robinson's buggy, (No. 2 report), and the time carefully noted by Mr. Cadell at Bedooba agrees within a minute or two of the times carefully noted at Rookwood, (Nos. 8, 9, 10.)

The explosion therefore took place immediately over the point at which the earthquake or tremor was most severely felt. It is described as like the noise of heavy cannon close to, and every detail seems to me to point conclusively to the cause of the earthquake as existing not in the earth but in the meteor. The explosions in great thunderstorms often shake the earth; and explosions of large quantities of powder or other detonating materials have similar effects, and there can I think be no doubt that meteors from time to time produce the same sort of earth tremors.

The object I had in view in collecting the facts of this meteor is now completed, but there are other facts pointing to the extraordinary brilliance and dimensions of this meteor, some or which I should like to call your attention to before I conclude.

ITS GREAT SIZE.

There are eleven estimates of the diameter of the meteor as compared with the moon, which was shining brightly at the time near the mid-heavens, and only one and a-half days from full moon. The estimates are admittedly rough, but they make the meteor's apparent diameter two and a-half miles, the intense brilliance of it no doubt exaggerated the apparent diameter: but the collateral circumstances, as for instance, its casting very dark shadows of trees, etc., in bright moonlight, at a distance of three

hundred and thirty miles, its effect upon the horse ridden by Capt. Honey, and many other details, prove that it must have been of magnificent proportions and brilliance.

ITS ALTITUDE.

Its altitude must have been very great. Capt. Honey having noted his own position and then that of the meteor in relation to large trees on the mountains near him, went back with an instrument and measured the altitudes of these points, which show that the elevation when first seen must have been one hundred and seventy miles, and at the moment of explosion ninety-six miles, and when last seen over the mountains thirty-three miles, but the probability is that it was then much farther away than three hundred and twenty miles assumed in the computation, and that therefore the third altitude is too small. I am aware that some of the best authorities deem it improbable that a meteor can become heated by the passage through the earth's atmosphere at a greater altitude than one hundred miles, and I do not press this observation as proof to the contrary, but I simply place it on record. It is to be regretted that not one of the observers referred the meteor's position to the stars. There are estimated angles of elevation which support Capt. Honey, (No. 10), made it eighty-four miles when first seen and sixty-two at explosion, and others, which although only estimated still prove that it must have been at a great elevation.

ITS BRILLIANCE.

I do not remember any meteor either here or amongst the records with a brilliance equal to this, which at a distance of at least three hundred and twenty miles could cast a much darker shadow than the moon. All who saw it were struck by the light it gave, which seemed like an electric flash-light, and at the time of explosion and later the light seemed for a short time of various colours. See Nos. 2, 7, 10, 11, 15, No. 11 especially.

The sketch map given between reports Nos. 1 and 2, is intended to show the localities of the places from which the meteor was seen, and as a matter of course the area over which it was seen.

THE CLIMATE OF LORD HOWE ISLAND.

By H. C. Russell, B.A., C.M.G., F.R.S.

[*Read before the Royal Society of N. S. Wales, October 2, 1895.*]

In working up the temperature records of this colony for a map, which I have made with a view of showing for each square degree of the colony, the mean annual shade temperature, the temperatures of spring, summer, autumn, and winter, as well as the highest and the lowest shade temperature ever recorded there on any day, I was very much struck by the mild climate of Lord Howe Island. Its surrounding currents of tropical water coming down from the north, no doubt keep the little island in a more equable climate than I anticipated, and I have brought the facts before you simply to place them on record, and to show by comparison with the mainland the advantages Lord Howe possesses in its climate, which may make it a sanatorium for those requiring a mild winter.

The records at Lord Howe Island extend over eight years. I have put with it, for comparison, the records at Sydney and on the New South Wales coast in the same latitude as Lord Howe Island.

Tabular Statement of the Climates of Sydney, Lord Howe Island and Port Macquarie.

	Sydney.	Lord Howe Island.	About Port M'quarie
Mean shade temperature...	62·9	68 6	65·3
Highest shade temp. ever recorded on any day	108·5	110·7	116·0
Lowest shade temp. ever recorded on any day	35·9	45·0	24 0
Spring mean shade temperature	62·9	68·0	65·6
Summer mean shade temperature	70·7	74·8	73·1
Autumn mean shade temperature	64·1	69·0	66·6
Winter mean shade temperature	54·0	62·4	55·7

Average Monthly Temperatures.

	Jan.	Feb.	Mrc.	Apl.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Sydney	71·4	70·9	69·3	64·5	58·5	54·4	52·5	55·0	58·7	63·3	66·6	69·7	62·9
Lord Howe Island ...	75·5	75·0	71·4	69·7	65·0	63·7	61·0	62·4	65·3	67 6	71·4	73·8	68·6
Port Macquarie District.	74·0	73·4	71·9	67·3	60 5	56·1	54·3	56·5	60·8	65·9	69·8	72 0	65 3

TYPES OF AUSTRALIAN WEATHER.

By Henry A. Hunt,

Second Meteorological Assistant, Sydney Observatory.

[With Forty Diagrams.]

In continuation of the valuable work on Australian Meteorology which the Hon. Ralph Abercromby initiated several years since, by offering a money prize for the best essay on Southerly Busters; he has recently selected the phases of Australian Weather which are treated in the following twenty studies of "Types of Australian Weather." Many of these appear to be peculiar to Australia, and at the same time connected with Equatorial and other weather. That they throw much new light upon the source of the greater part of Australian rain, and show how these rain storms develop out of ordinary weather conditions is certain; at the same time they form an important contribution to the study of weather in the Southern Hemisphere generally. The work has been done by Mr. H. A. Hunt, at Mr. Abercromby's expense, and Mr. H. C. Russell, has edited the work.

GENERAL REMARKS.

As a general rule, weather is set fine when anticyclones move rapidly, and in a straight line across Australia, *i.e.*, at a rate exceeding five hundred miles per day. And weather is unsettled when they move slowly, and not in a straight line, *i.e.*, in a zigzag line, especially if they show no appreciable forward motion for a day or two. When anticyclones move in low latitudes the conditions favour dry weather, in high latitudes, wet weather, especially if they rest for a time south of South Australia.

All the examples of weather phases which follow have been selected from the Sydney Weather Charts, and illustrate each type. The originals were carefully traced, and then reduced from 22″ × 17″ to the size used in this essay by means of the camera.

Ordinary symbols have been used, except the circle half filled for thunderstorms, and the straight line shading; parallel lines indicate the area of rainfall under one inch, crossed shading over one inch.

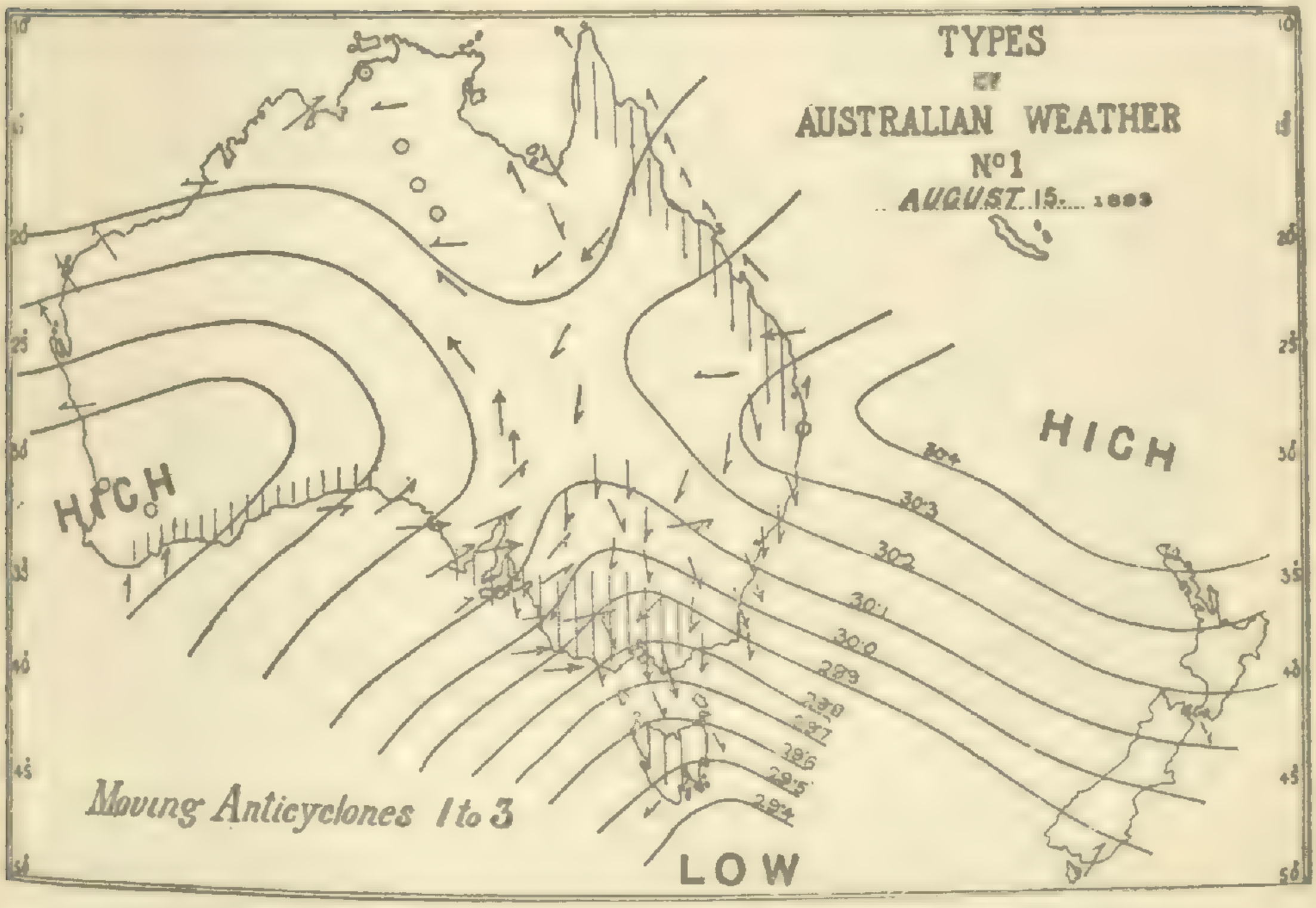
TYPE I.—MOVING ANTICYCLONES.

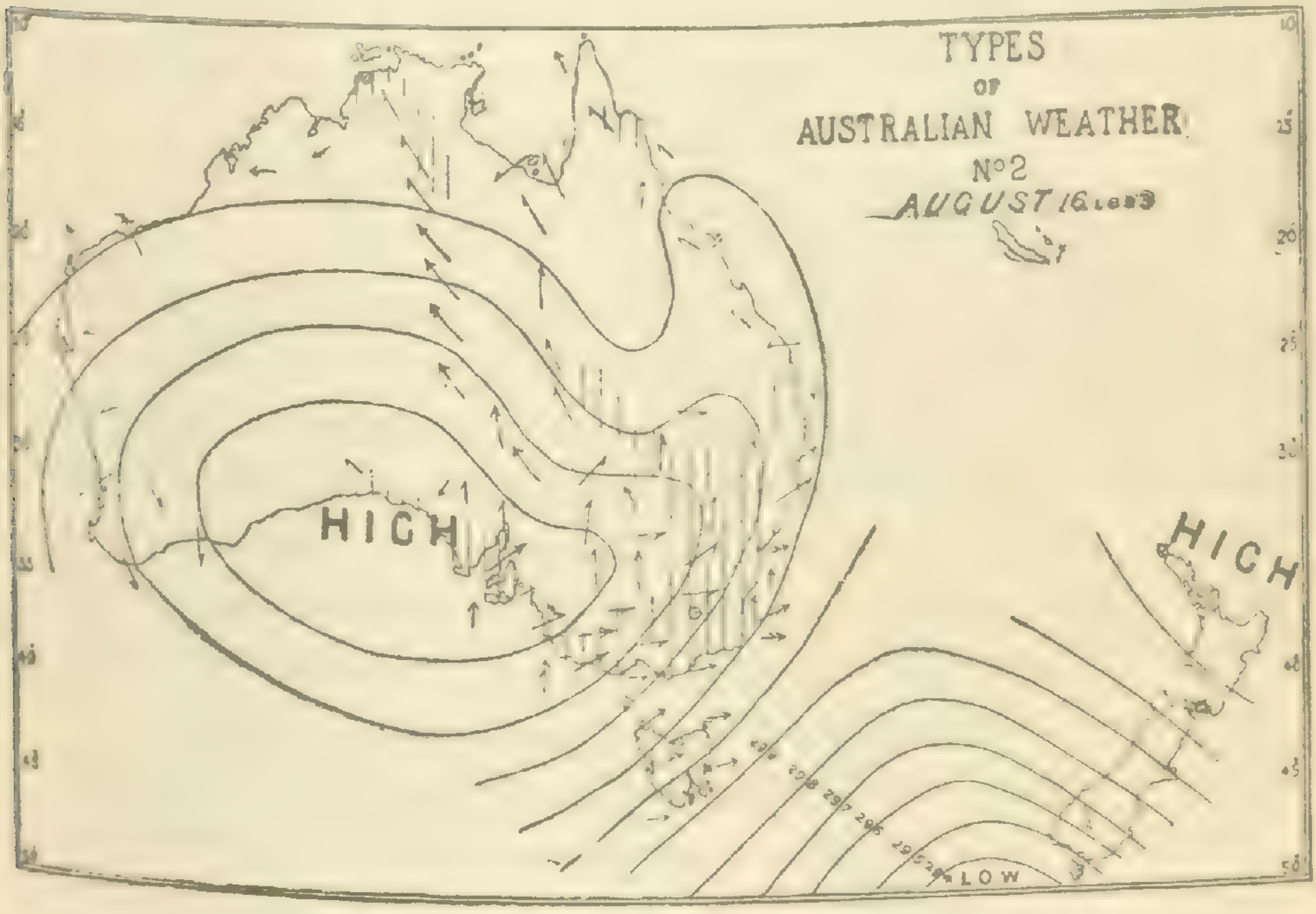
One of the best marked features of Australian weather is the steady easterly progression of all the types, and the governing type, that in fact about which all the other types seem to congregate, is the anticyclone; it has therefore been placed first in the series, with three charts to show the progress made by a quick moving one in forty-eight hours. The average daily progress of anticyclones is four hundred miles per day, but the speed at times rises to one thousand miles.[1]

Investigation so far leaves no room to doubt that in these latitudes a series of anticyclones surround the globe; the latitude of the average one varies with the season, being farther south in summer than in winter. The normal circulation about an anticyclone brings southerly winds in front of them, and northerly winds in the rear, hence our cold and our hot winds.

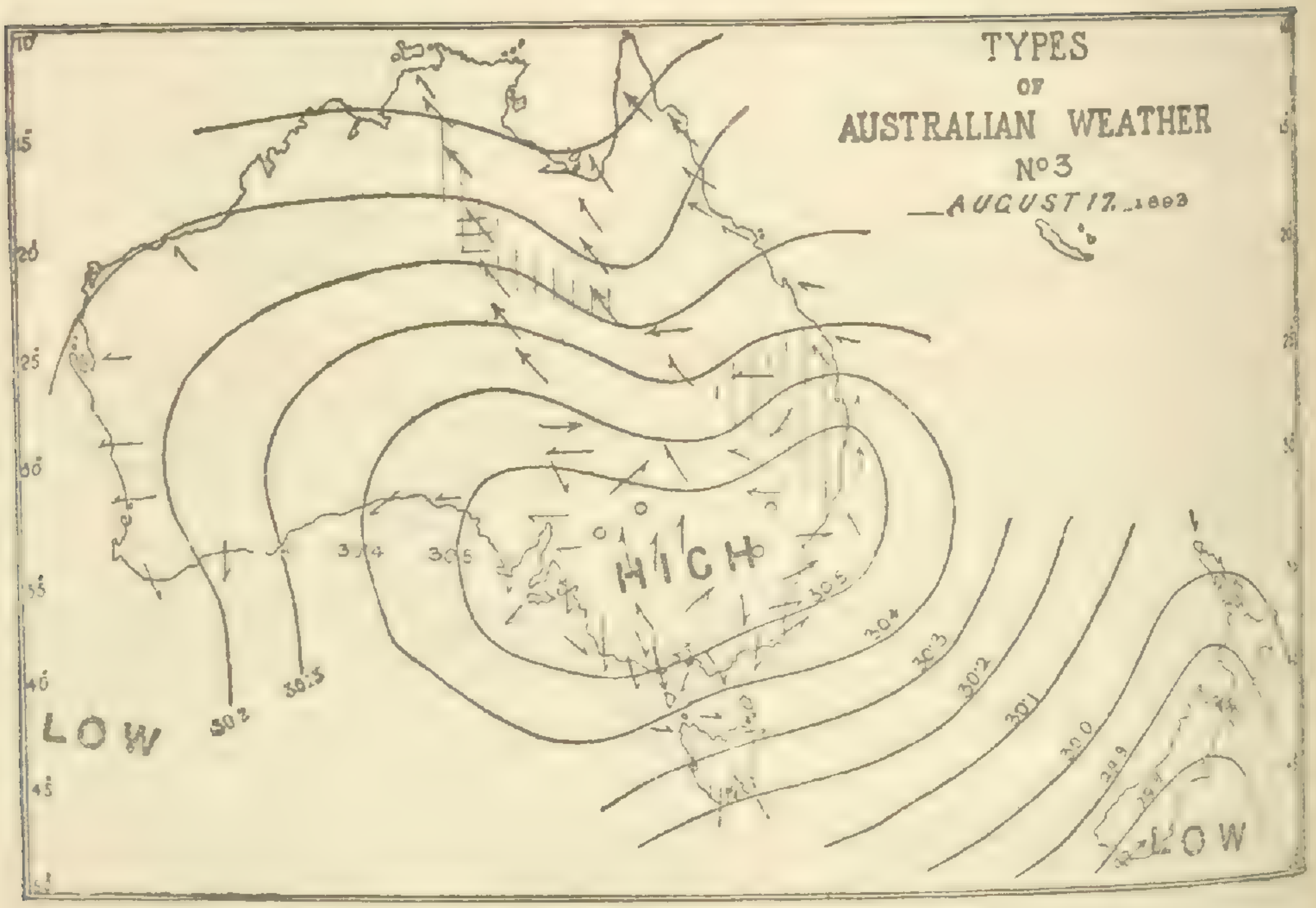
Chart No. 1 shows the position, on 15th August, 1893, of the eastern half of an incoming anticyclone; it rests over Western Australia, while the departing one is seen over the Tasman Sea; between these is seen the usual ∧ depression, which is of average intensity, and a dormant tropical low pressure to the north. In Chart No. 2 the anticyclone has moved nearly nine hundred miles in the twenty-four hours, the centre being located near Fowler's Bay, north of the Australian Bight; the antarctic ∧ depression is well across the Tasman Sea, while the tropical or monsoonal isobar depicted in the previous chart has apparently merged into the high pressure system, a curious and not unusual kink being formed to the north-east of it, following the contour of the Gulf of Carpentaria. On Chart No. 3 the anticyclone is shown to have moved a further seven hundred and fifty miles, or a total of

[1] Russell—Quarterly Journal R. M. S., Vol. XIX., No. 85.





one thousand six hundred and fifty miles in forty-eight hours; the monsoonal dip is still noticeable south of the Gulf, while the antarctic Λ depression has its centre to the east of New Zealand.



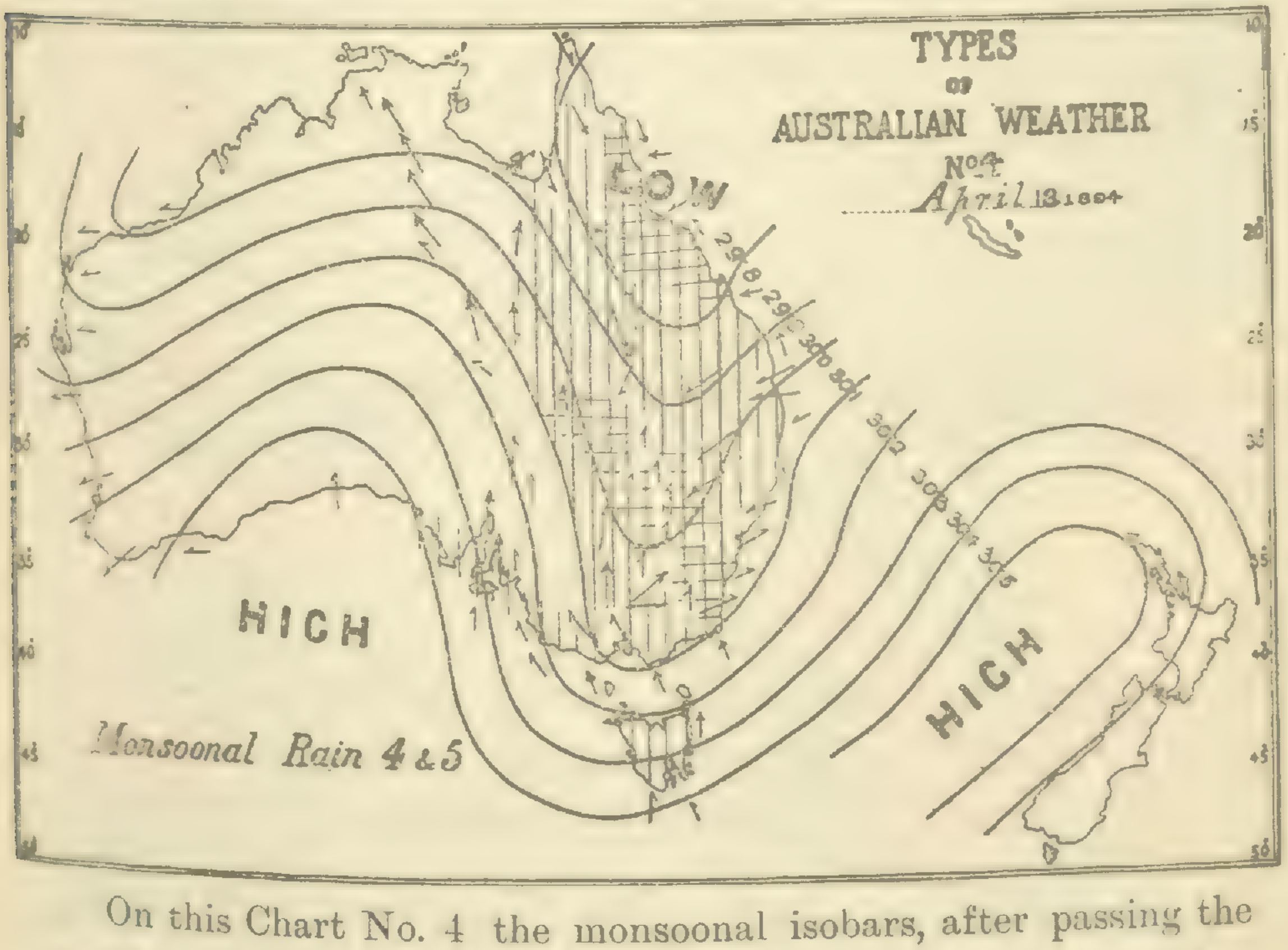
The passage of this anticyclone was an unusually rapid one, and is presented as portraying with a minimum number of charts the easterly motion of anticyclones over Australia.

TYPE II.—MONSOONAL RAIN STORM.

This type is undoubtedly the chief rain agent in the Australian Continent. Monsoonal depressions or tongues may occur at any time of the year, but particularly between the months of September and April, and most frequently during January, February and March. The readings of barometers in the depression seldom fall very low, the grade from the surrounding areas to the centre of the tongue ranging from one to three-tenths of an inch generally: the depression may intensify, that is the tongues between high pressures may protrude further south anywhere during their passage across Australia, but show a preference to do so after they have crossed central Australia, a fact which suggests that the heated interior has at least some influence in their development.

When and wherever the tongue is well defined, rain certainly follows in its track, and thunderstorms as a wide spread and simultaneous feature are never experienced without it.

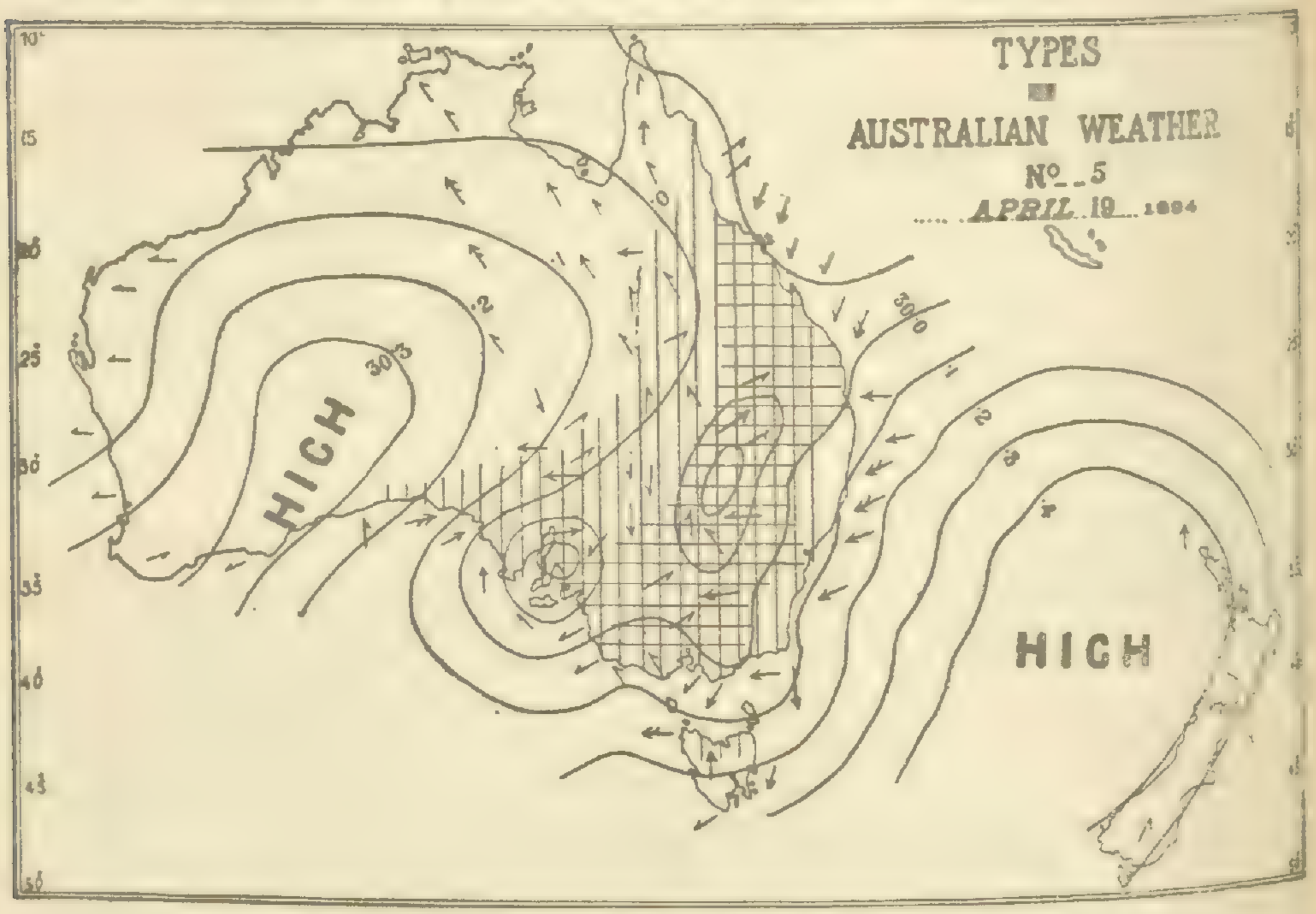
On April 18th and 19th, 1894 (Chart Nos. 4 and 5) occurred one of the finest monsoonal rain storms on record, the area affected being very extensive, embracing the whole of the eastern colonies, Tasmania, and the greater part of South Australia. Many inches —up to five and six—of rain were recorded on the north-east coast of Queensland, and over the eastern half of the rain area the country benefitted to the extent of over two inches generally before the storm was over.



On this Chart No. 4 the monsoonal isobars, after passing the most southern part of the tongue, are shown sweeping round a high pressure of considerable energy, situated over the Great Bight. Following these isobars to the eastward, we find them recurving over another high pressure of greater energy in the Tasman Sea. On Chart No. 5, both anticyclones will be noticed to have worked northward, and while so doing they have lost somewhat in pressure, and the low pressure tongue has extended further south and broadened ; at the tip, two cyclonic rain centres will be observed to have formed.

The chart antecedent to 18th April presented the general characteristics of Chart No. 1, except that the antarctic ʌ depress-

ion was a considerably *less active* feature, but on the other hand the monsoonal dip was somewhat more pronounced, and possessed two instead of one isobar. Following the 19th, the chart of 20th revealed no sign of the monsoonal tongue, and the continent was covered with a high pressure of very slight energy.

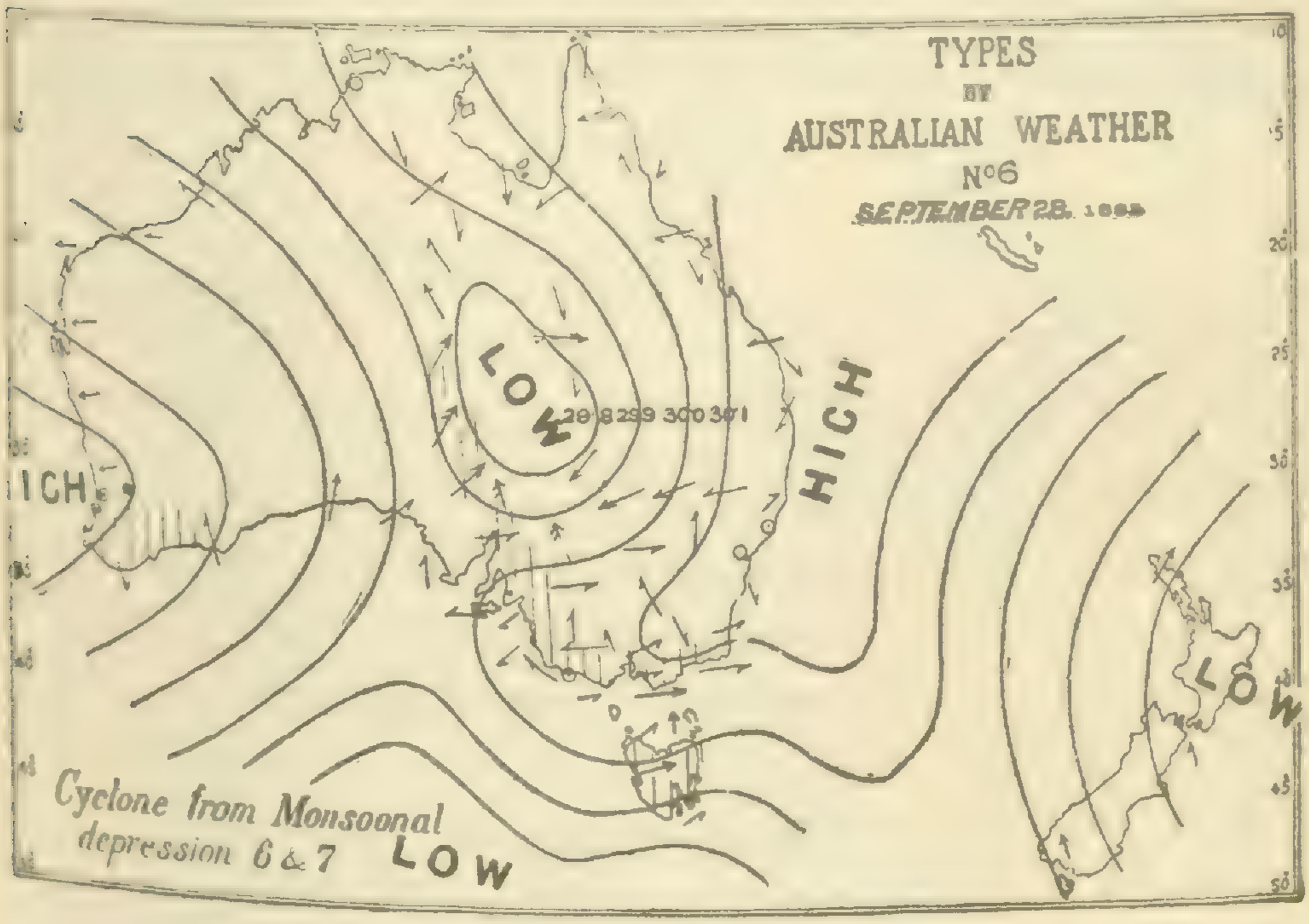


TYPE III.—DEVELOPMENT OF A CYCLONIC STORM IN LOW LATITUDES FROM A MONSOONAL DEPRESSION.

In Type No. 3 we have the development of a cyclonic storm out of a monsoonal depression. The seasonal peculiarity of this phase of the tropical low pressure is similar to that in Type No. 2. The cyclone seems to develop when the southern extension of the monsoon is out of proportion to its width, and it becomes so narrow at one part of it that the opposing winds which circulate round it interfere, set up the cyclonic circulation, and it then progresses eastward as a rain storm. (See Charts 6 and 7.)

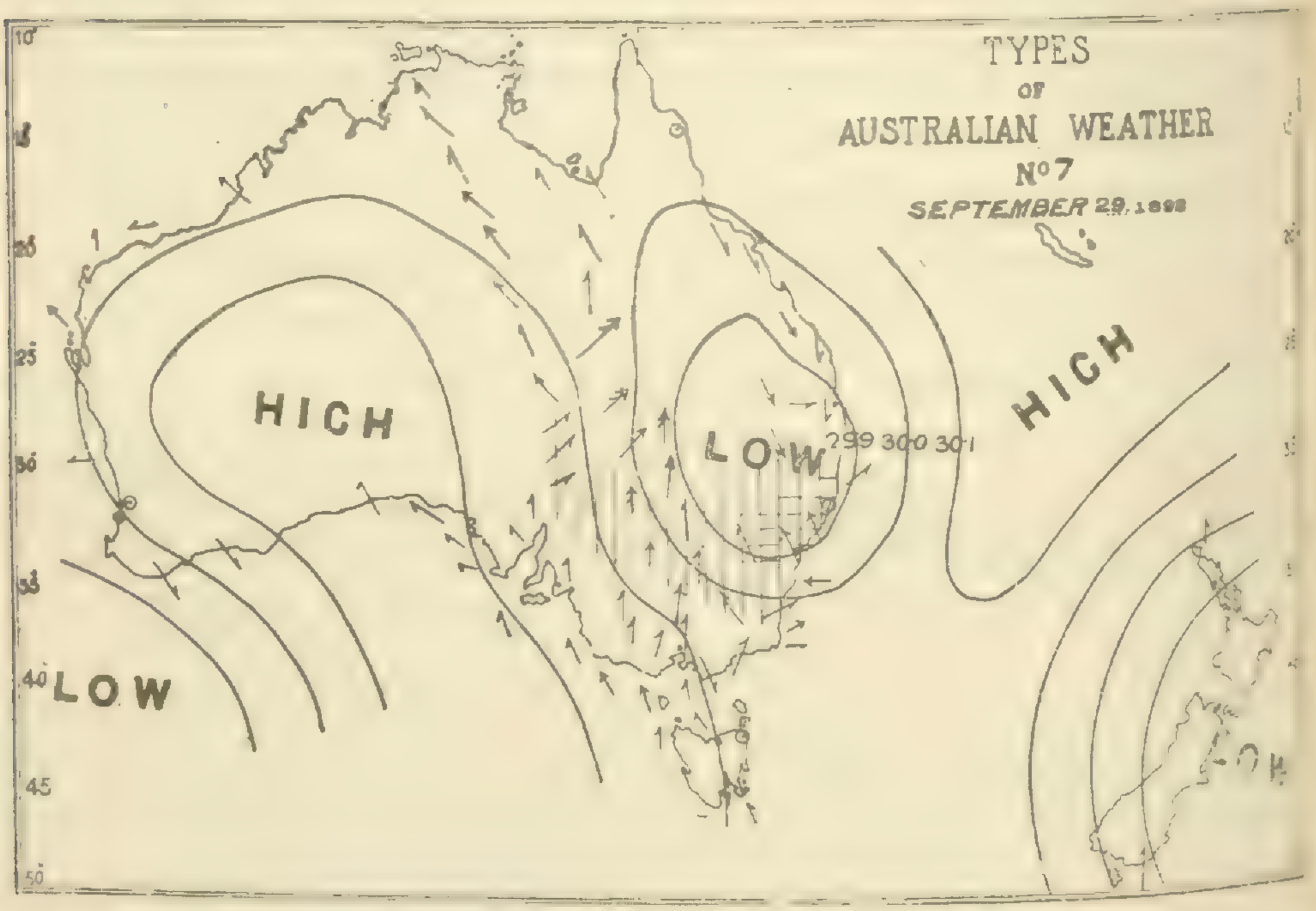
These storms frequently develop in South-east Queensland, and they are generally most severe there; the quantity of rain which sometimes comes with them is very remarkable, as in the case of the phenomenal flood in Brisbane in 1893, which was the result of one of these storms.

The example selected and shown in Charts 6 and 7 took place on September 28th and 29th, 1892; on the 28th (Chart 6), it appears that one of these storms had developed in the previous twenty-four hours, at the southern end of a narrow tropical or monsoonal tongue of low pressure. An anticyclone of good energy lies to the east of it, with its isobars extending well to the north and contracting the width of the tongue in the north: another anticyclone lies to the west, and this also seems to be pressing on the narrow monsoonal tongue and helping to contract its diameter, at the same time the energy in both high pressures is adding force to the circulation of the wind, and so aiding in the development of the cyclonic circulation. A modified \ depression exists to the south-east of the Australian Bight, and there is another over New Zealand.



On September 29th, (Chart 7), the small cyclone has extended its area and energy on its way to the coast, but its motion of rotation has been rapid, and this probably accounts in a measure for the comparatively small area over which rain has fallen, although, in this instance, over an inch of rain fell in the central

and eastern parts of New South Wales. The winds circulating about the western isobars of this storm are rather stronger than usual in such cases. In the twenty-four hours both anticyclones have lost a considerable portion of their energy, while that of the depression in New Zealand is about the same as on the previous day.



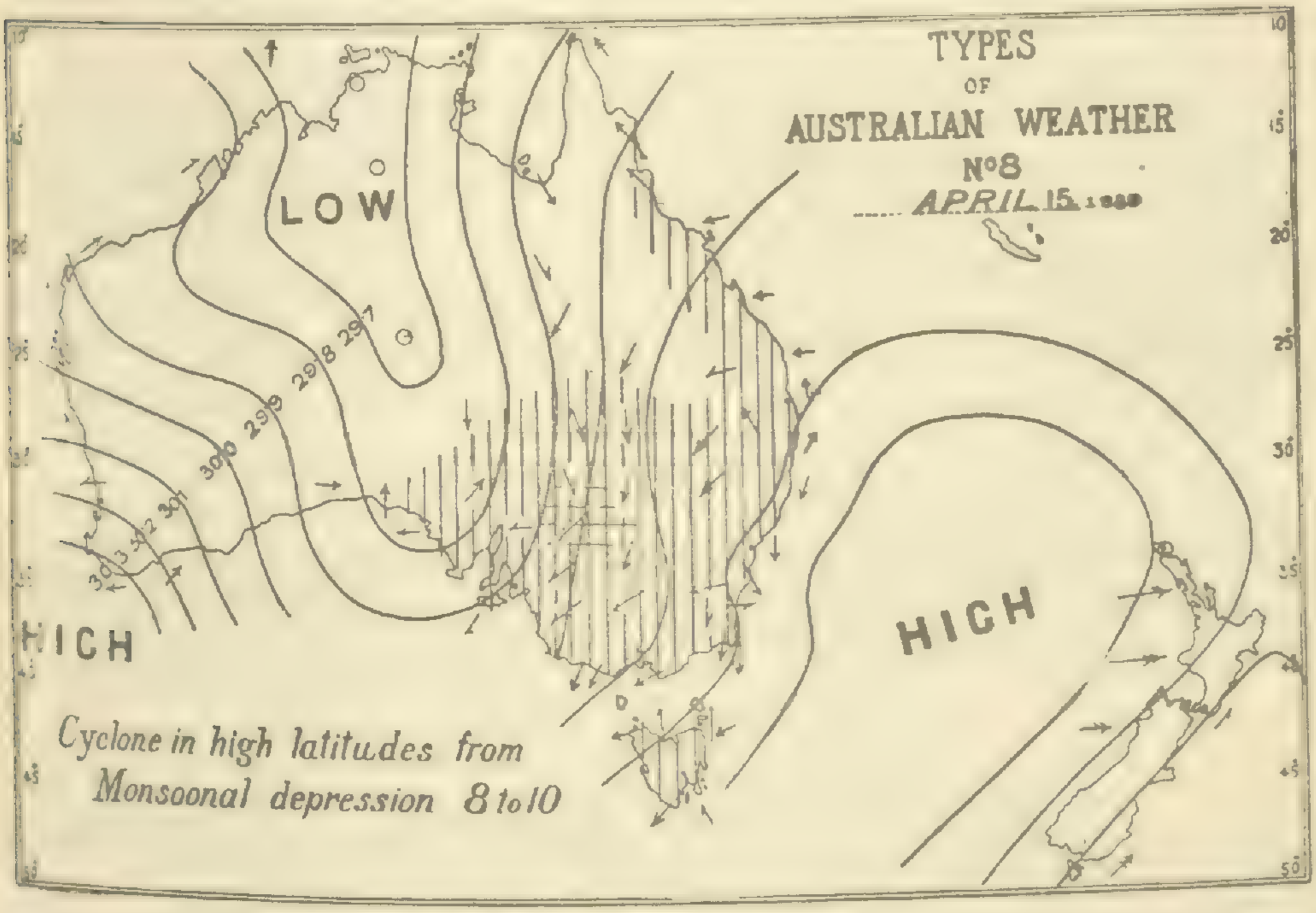
TYPE IV.—DEVELOPMENT OF A CYCLONIC STORM IN HIGH LATITUDES FROM A MONSOONAL DEPRESSION.

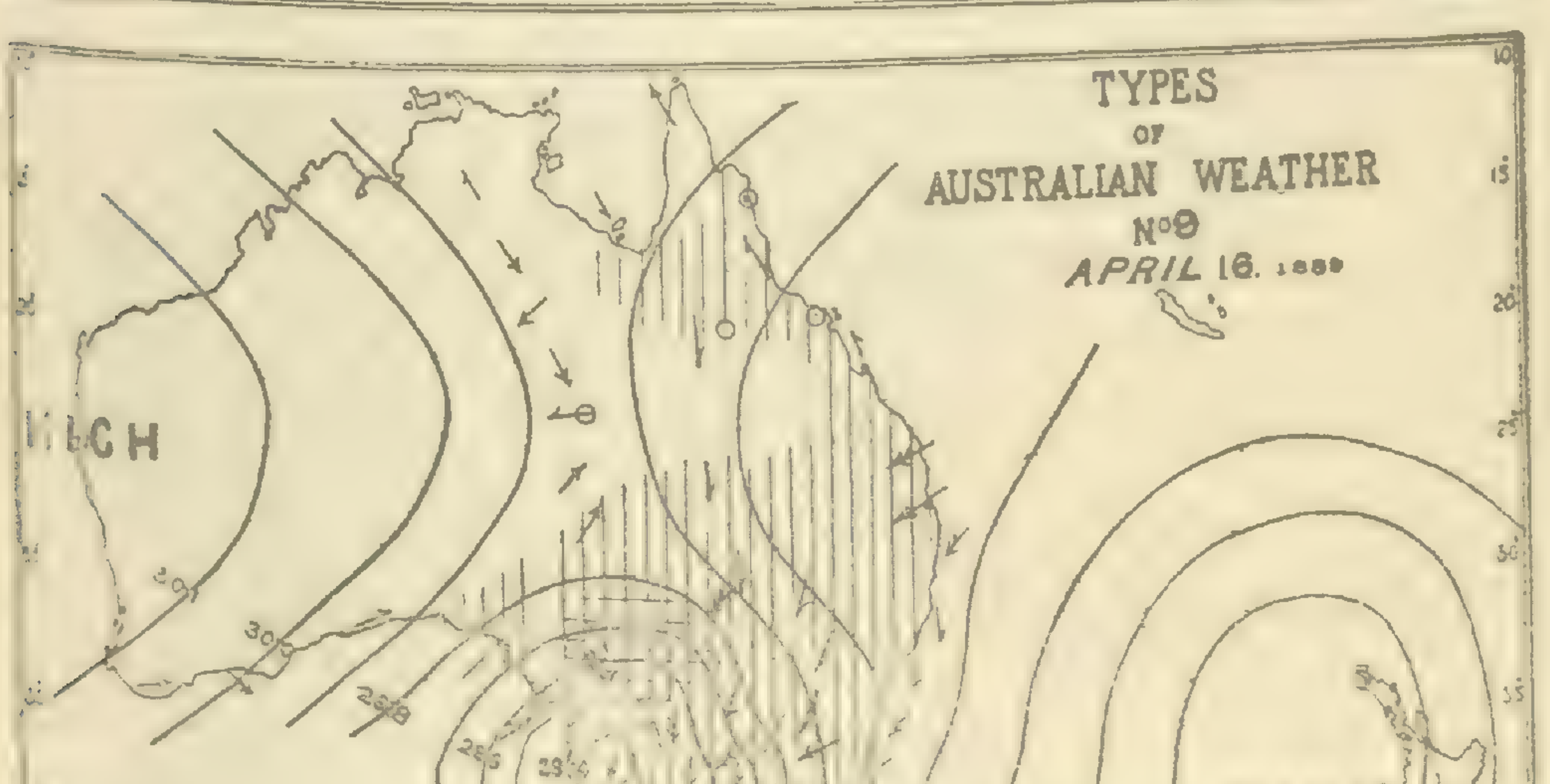
These are somewhat similar to Type 3, but the rainfall is usually not so heavy, and the wind much more violent.

Chart No. 8 shows the development of one of these cyclones on April 15th, 1889; in this case the monsoonal depression had extended across Australia into the Australian Bight. The development of one of these storms is heralded by the strong easterly gales on the south-east coast of South Australia and south coast of Victoria. The energy of wind circulation increases over South Australia, and as the whole system moves bodily eastward from the Australian Bight to the mainland, the circulation is seen to be that of a fully developed cyclone of small area, with a

diameter three to five hundred miles, formed out of the southern part of the extensive monsoonal depression.

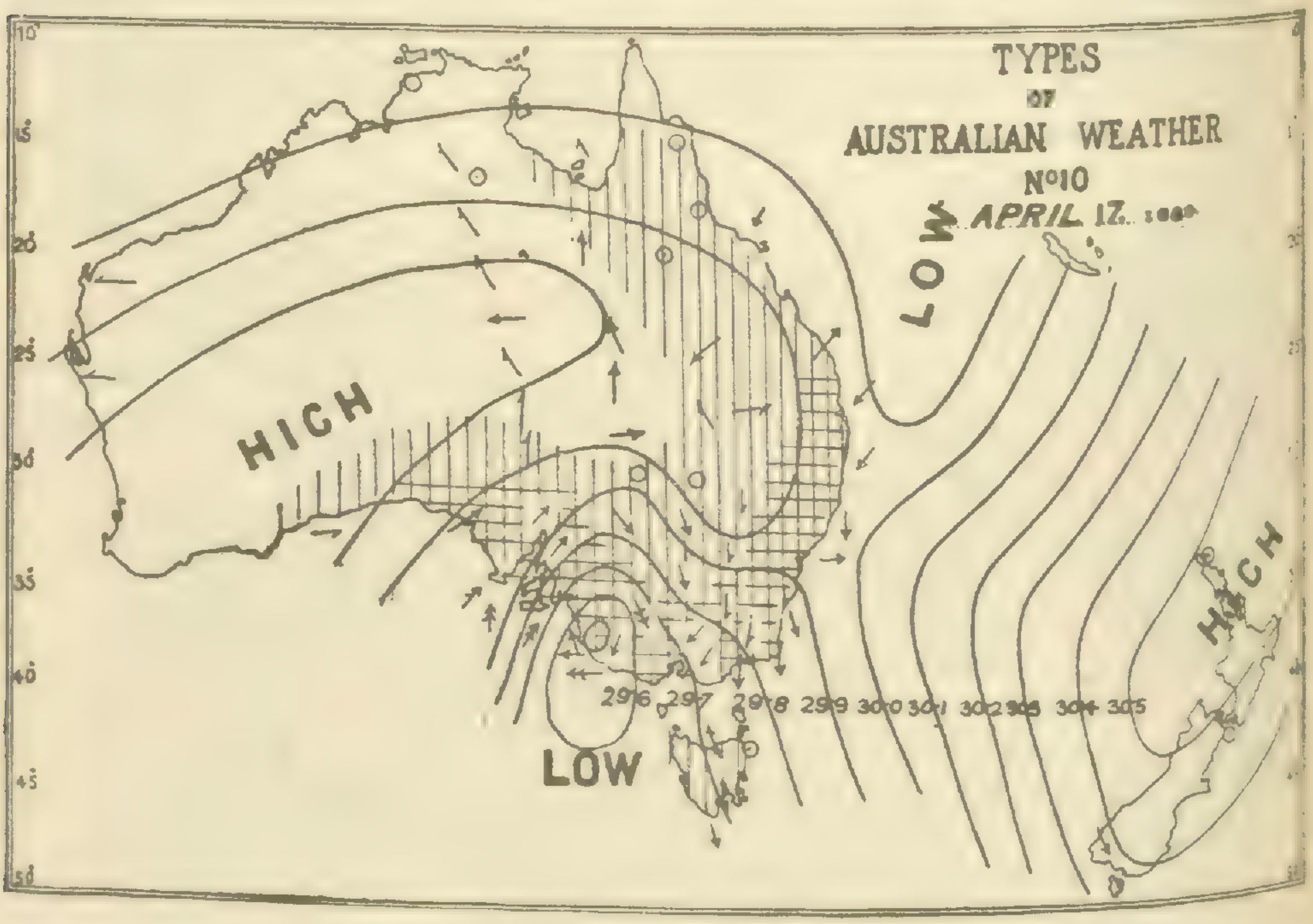
In Chart 8 a high pressure is shown over the south-western part of Australia, and evidently encroaching on the moonsoonal about central Australia.





In Chart 9, the western anticyclone has extended northwards and has seriously contracted the diameter of the monsoonal low pressure, thereby facilitating or helping to cut off and start the cyclonic storm in the south; which has now developed a much steeper barometric grade and an energetic wind circulation, and is moving eastward without extending the rain area.

Chart No. 10 shows comparatively little motion in the cyclone, but it is considerably distorted, especially to the west, where the anticyclone is compressing the isobars by its easterly progress and in its endeavours to maintain its rate has overridden the cyclone in the north. As will be seen by a glance at these three charts, the rain resulting from this storm was most extensive and beneficial, and the winds under its influences were strong.

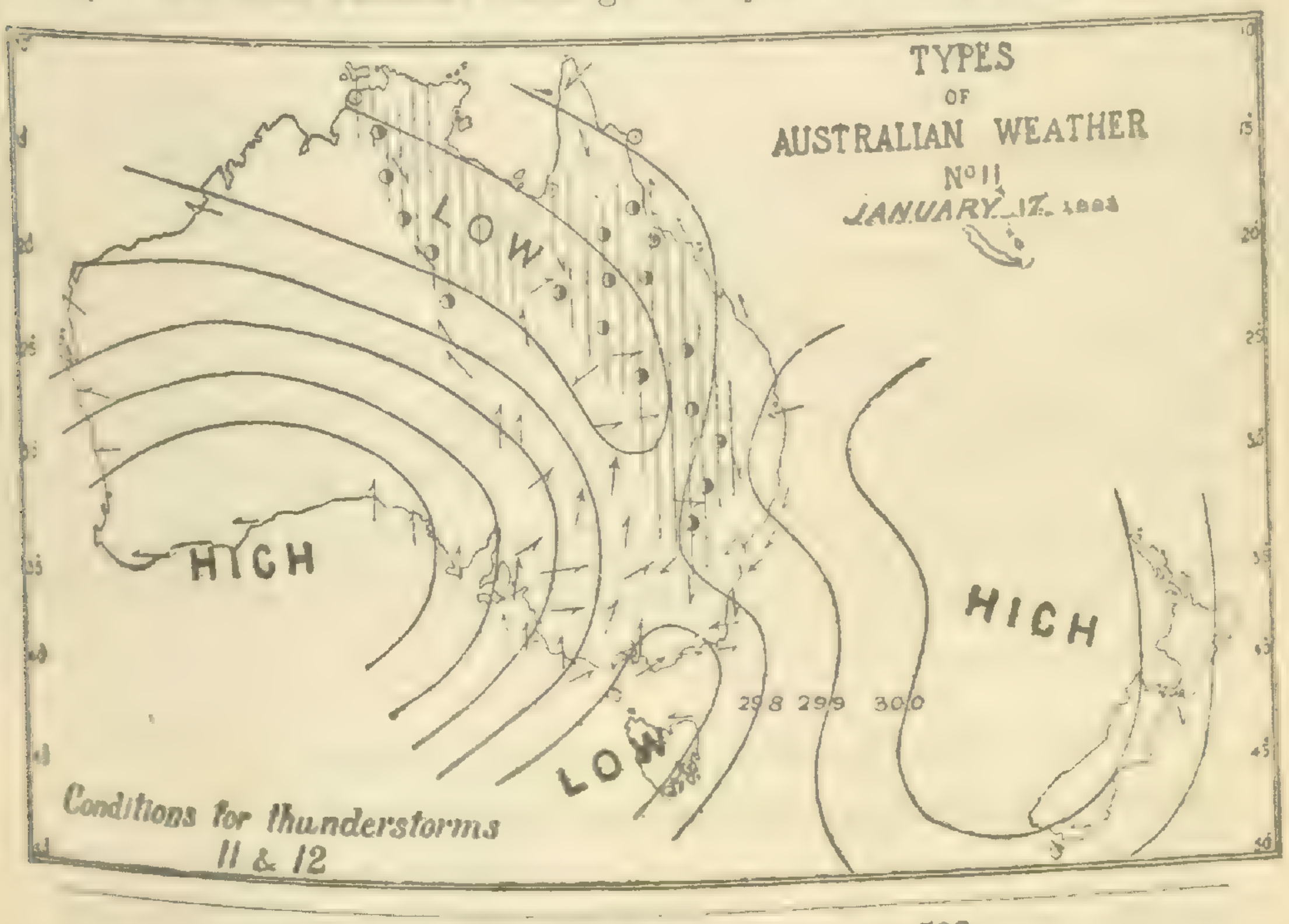


TYPE V.—CONDITIONS FAVORABLE FOR THUNDERSTORMS.

Upon comparison of charts setting forth this type with those of cyclonic thunderstorms, they will be found very similar; the main difference being the absence in this set of the cyclonic area at the end of the monsoonal tongue. The chief feature indicating

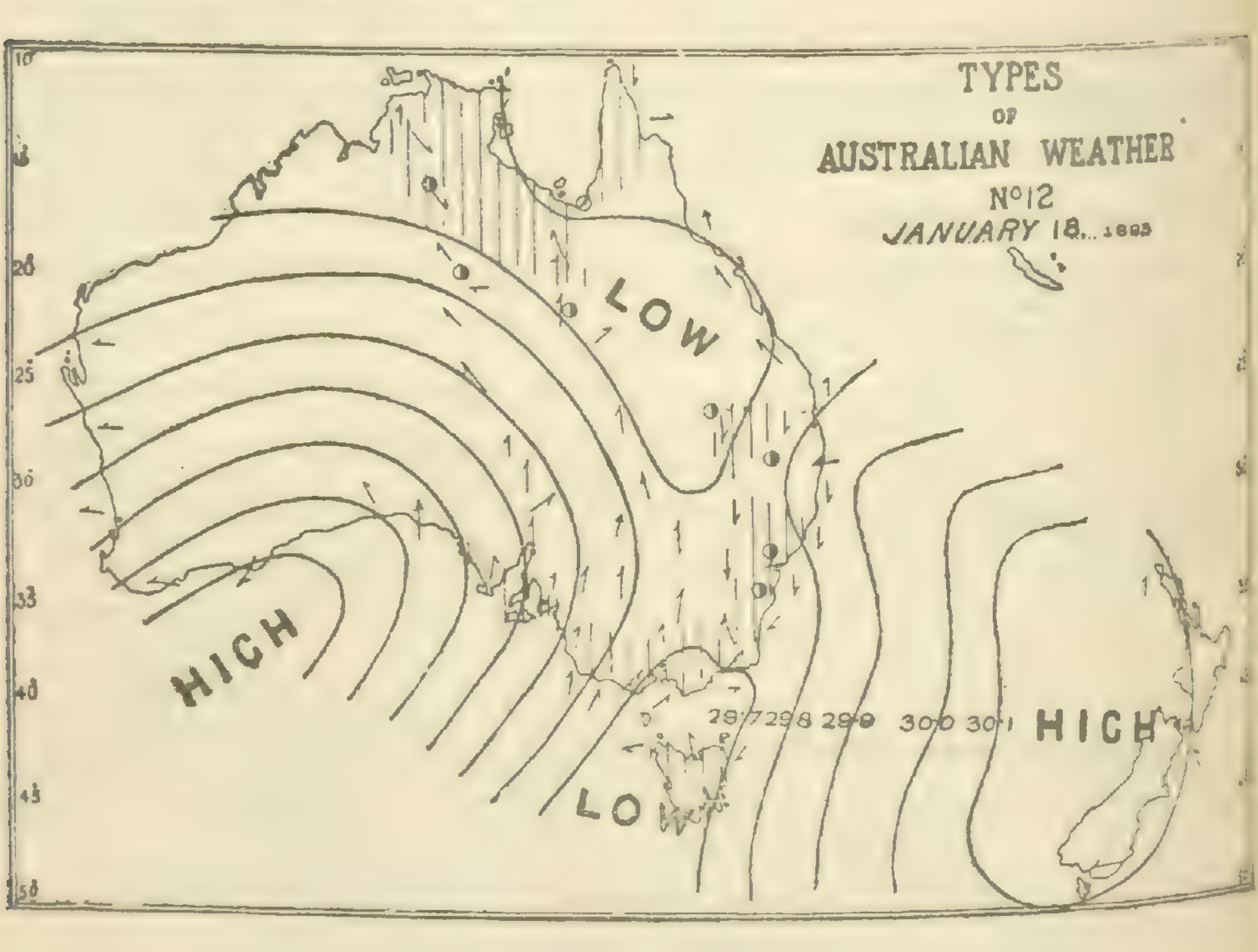
thunderstorms is the narrowness of the col[1] and somewhat congested state of isobars in the high pressures west and east of it, resulting in opposing winds. Those of the tropical tongues are hot and charged with moisture, while those of the \ depressions are strong and dry. This type is met with during the monsoonal season. The rains resulting from this feature are not generally heavy, and though thunderstorms may be experienced over extensive areas of Queensland, New South Wales, and Northern Territory, a number of them may occur without any rain falling.

Chart No. 11, January 17th, 1893, shows an extended and narrow tongue lying between two relatively high pressures, a A depression similarly situated also exists in the south, this col or area of low pressure separating these two depressions is very small, and opposing currents of wind are noted there as blowing within close limits. Thunderstorms were occurring or had occurred in Northern Territory generally, over a great part of Queensland and in central parts of New South Wales, the rains upon this occasion, as is often the case, were not heavy, though they fell over an extensive and generally unfavoured area.



[1] For explanation of this term see p. 532.

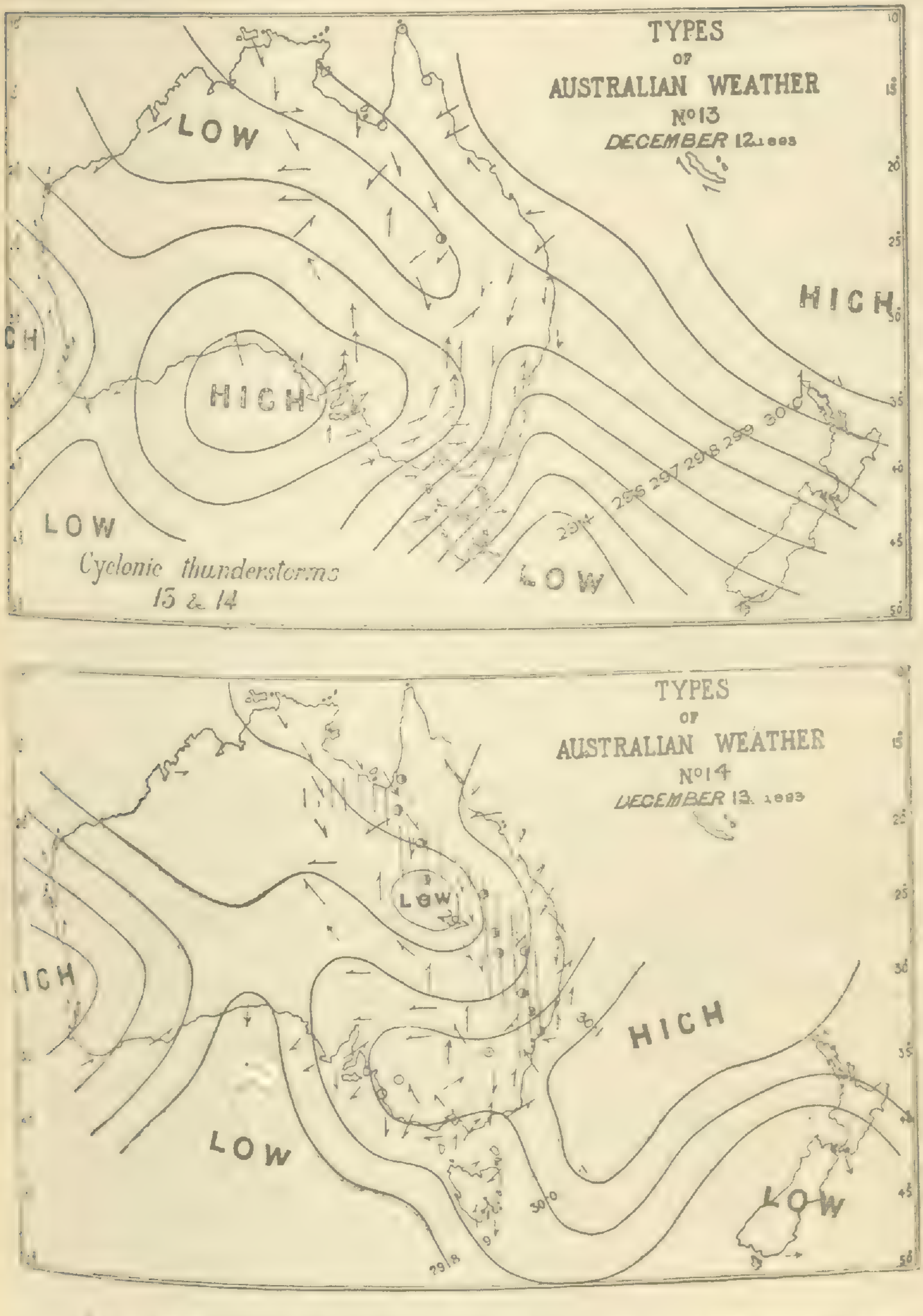
On Chart No. 12, the following day, though a few storms were recorded, shows a great diminution in number. The col has widened and the monsoonal tongue has lost to some extent its thundery characteristics, having widened at the end. The accompanying barometric systems show no motion since the previous day, but the high pressures have intensified.



TYPE VI.—CYCLONIC THUNDERSTORMS.

This also, like the preceding one, is allied to the tropical low pressures, but in this case a defined cyclonic circulation develops in the lower extension of the tongue without the usual intensification of grades. From this source the thunderstorms radiate in easterly and southerly directions, and at times, as in the instance presented, a vast area is affected.

Chart No. 13, December 12th, 1893. As on the previous set the monsoonal tongue lies over much the same country, though with its axis more east and west; the high pressure to the west is very small, and the systems are somewhat fragmentary.



On the following day, Chart No. 14, a cyclonic circulation has formed in the end of the tongue, while the A depression over Sydney on the 12th has moved eastward and nearly filled up, and the high pressures have followed and intensified. The thunder-

storms and rains were not so general as on the thunderstorm type, but curiously, were recorded in an almost parallel area of country, nearly three hundred miles wide by twelve hundred long. Though great barometric changes have taken place, the pressures remain about the same as on Chart No. 13.

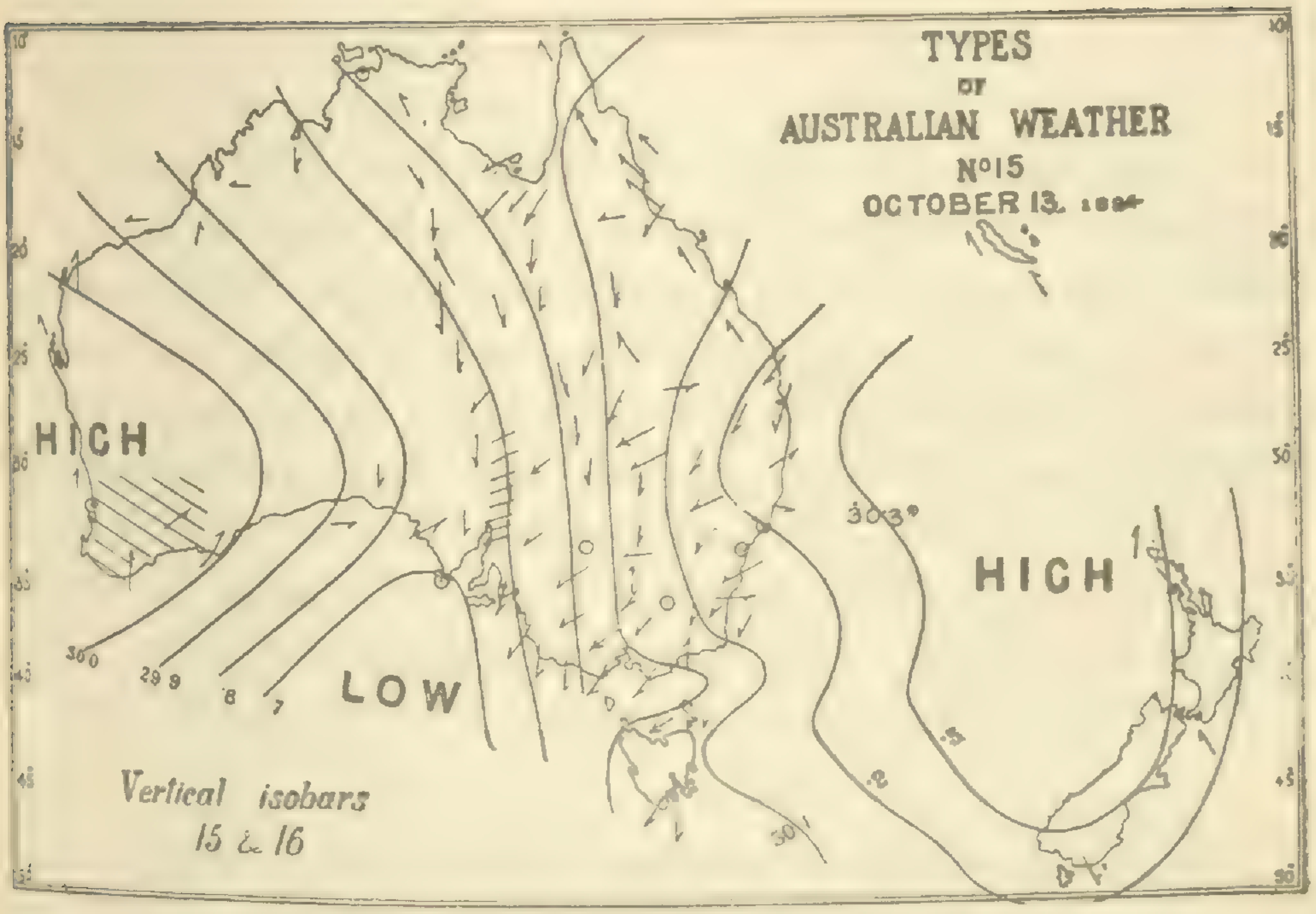
TYPE VII.—A RAIN STORM WITH VERTICAL AND NEARLY STRAIGHT ISOBARS.

This type is one of the best defined and reliable of the series for forecasting purposes, because with them, good general rains almost invariably come. They are the rear isobars of a departing anticyclone, and the wind circulation from north and north-east brings into the interior winds laden with tropical moisture to meet in the west southerly winds laden with antarctic cold, and therefore precipitating power. The sequence of rain is rendered even more certain if rain be recorded in the north-east before the isobars straighten, or in the ∧ depression to the south.

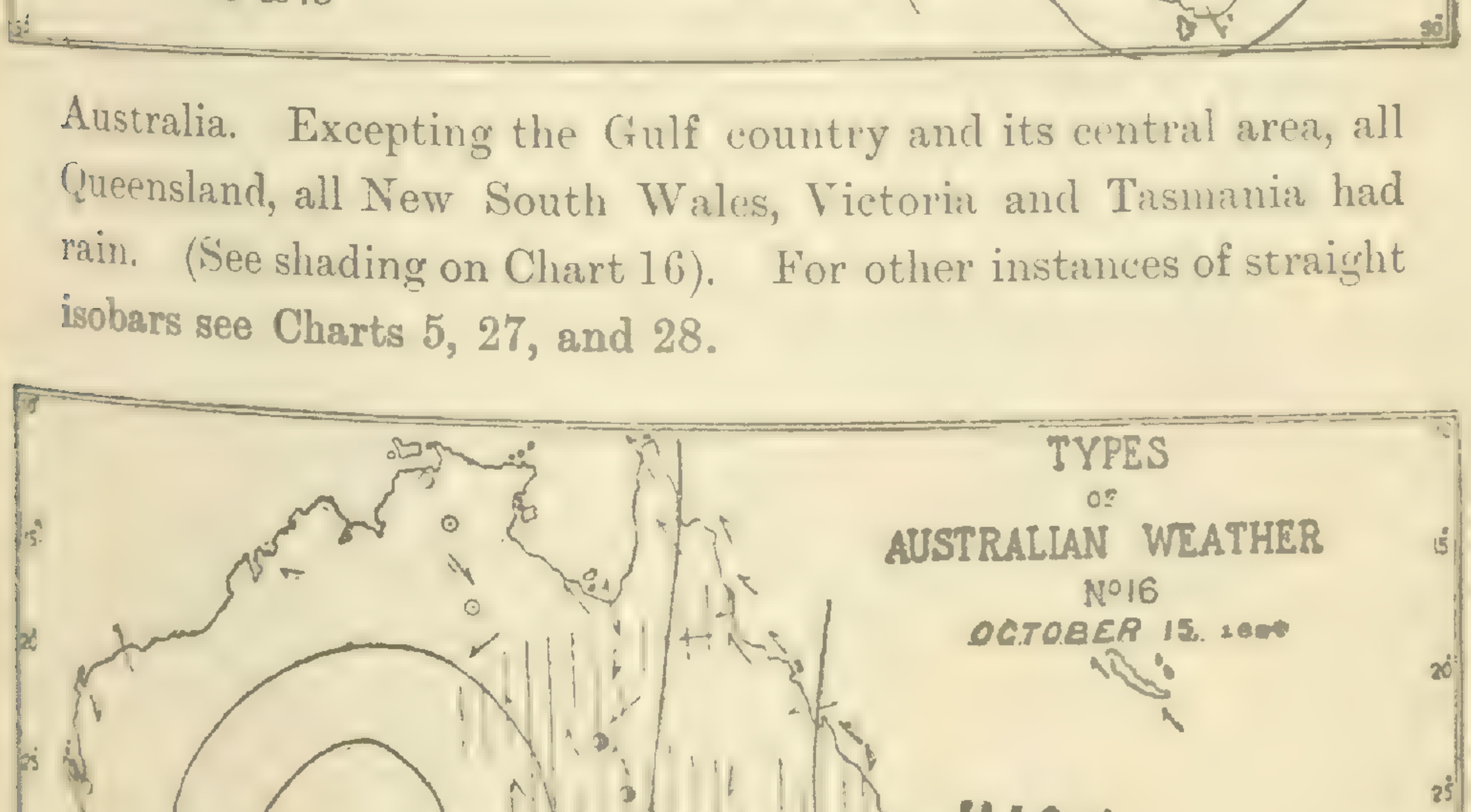
The actual height of the barometers is not material, but the greater the number of isobars in a given area, the more extensive will be the rainfall ; the rain usually lasts three days. The rain begins to fall north-west of New South Wales, spreads southwards, then eastward, and finally northwards, crossing the mountains near the Queensland boundary. A fine example of this type occurred on 15th, 16th, and 17th October, 1894. (Charts 16, 17.)

On the 15th, Chart 16, a departing anticyclone rests over Tasman Sea, and its rear isobars are shown running north and south over central Australia ; another anticyclone is shown over Western Australia and a ∧ depression east of the Australian Bight ; a trough of low pressure rests over Central Australia from north to south. On this day the only indications of the pending rain were found in the cloudy skies generally over South Australia, western parts of New South Wales and Queensland, and a small area of rain in South Australia.

In Chart 16, the straight isobars of Chart 15 have entirely disappeared, but the rain has come over Central and South



Australia. Excepting the Gulf country and its central area, all Queensland, all New South Wales, Victoria and Tasmania had rain. (See shading on Chart 16). For other instances of straight isobars see **Charts 5, 27, and 28.**



TYPE VIII.—CYCLONES FROM NORTH-WEST.

From time to time fully developed cyclonic storms appear on the north-west and west coasts of Australia, and in the Australian Bight, but the absence of observing stations in the unoccupied country which lies between the overland telegraph line and the west coast of Australia, makes it impossible to trace them over that part of the continent, but cyclones are well known on the northern coast of Western Australia, and their formation in the tropics equally well known. There can therefore be no doubt that when we find a cyclone on the western coast of Australia or in the Australian Bight, that it is one which has come from the north-west, and is in fact recurving to the east and south-east as they do on the east coast.

The one selected for Type 8 was picked up on the west coast of Australia in Latitude 28° on July 4th, 1892, (See Chart No. 17). The winds were light, but the rain heavy along the coast; an inert anticyclone rested over South Australia, Victoria, and New South Wales, where it was moving to the east and making room for the approaching storm.

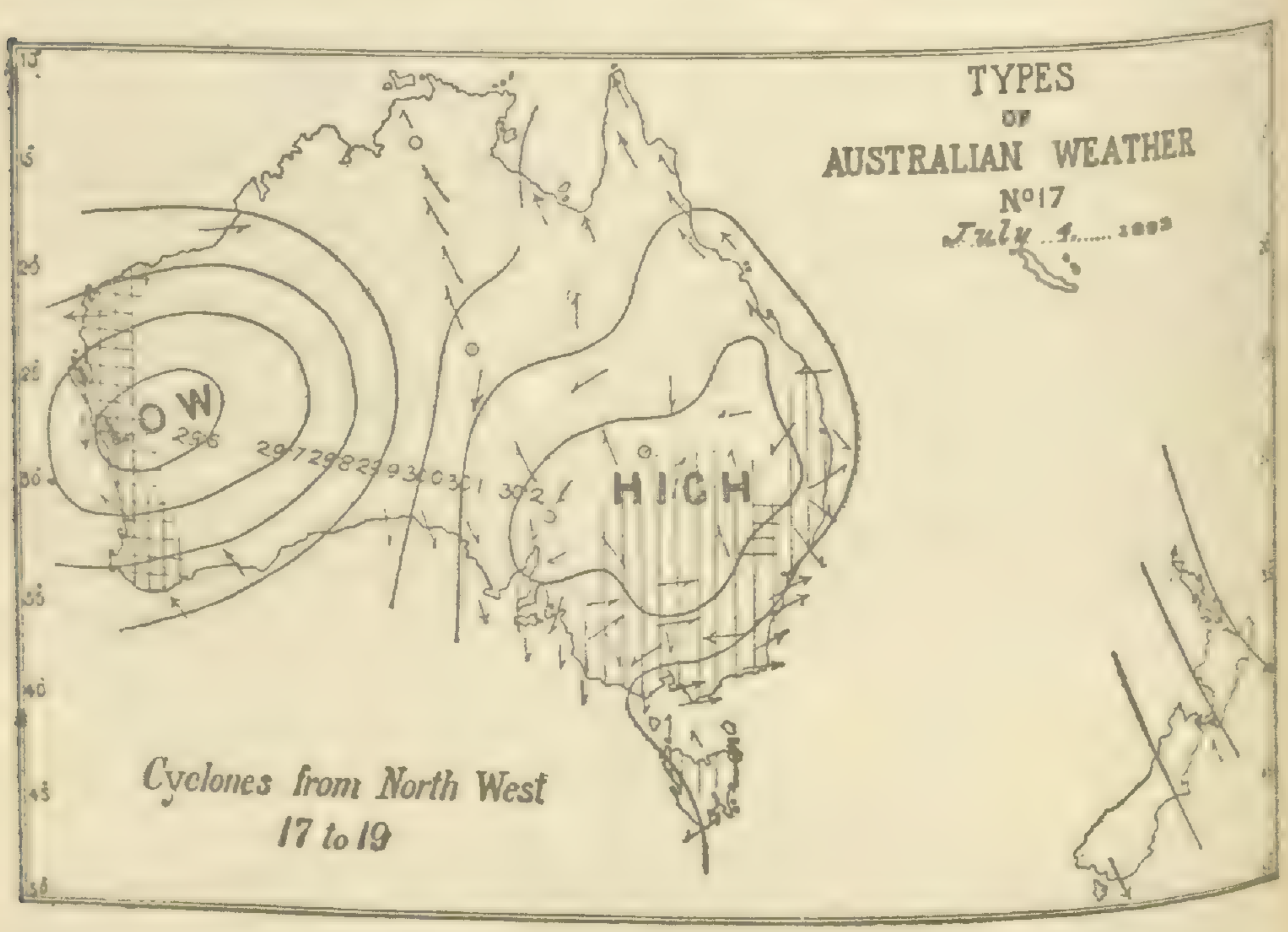
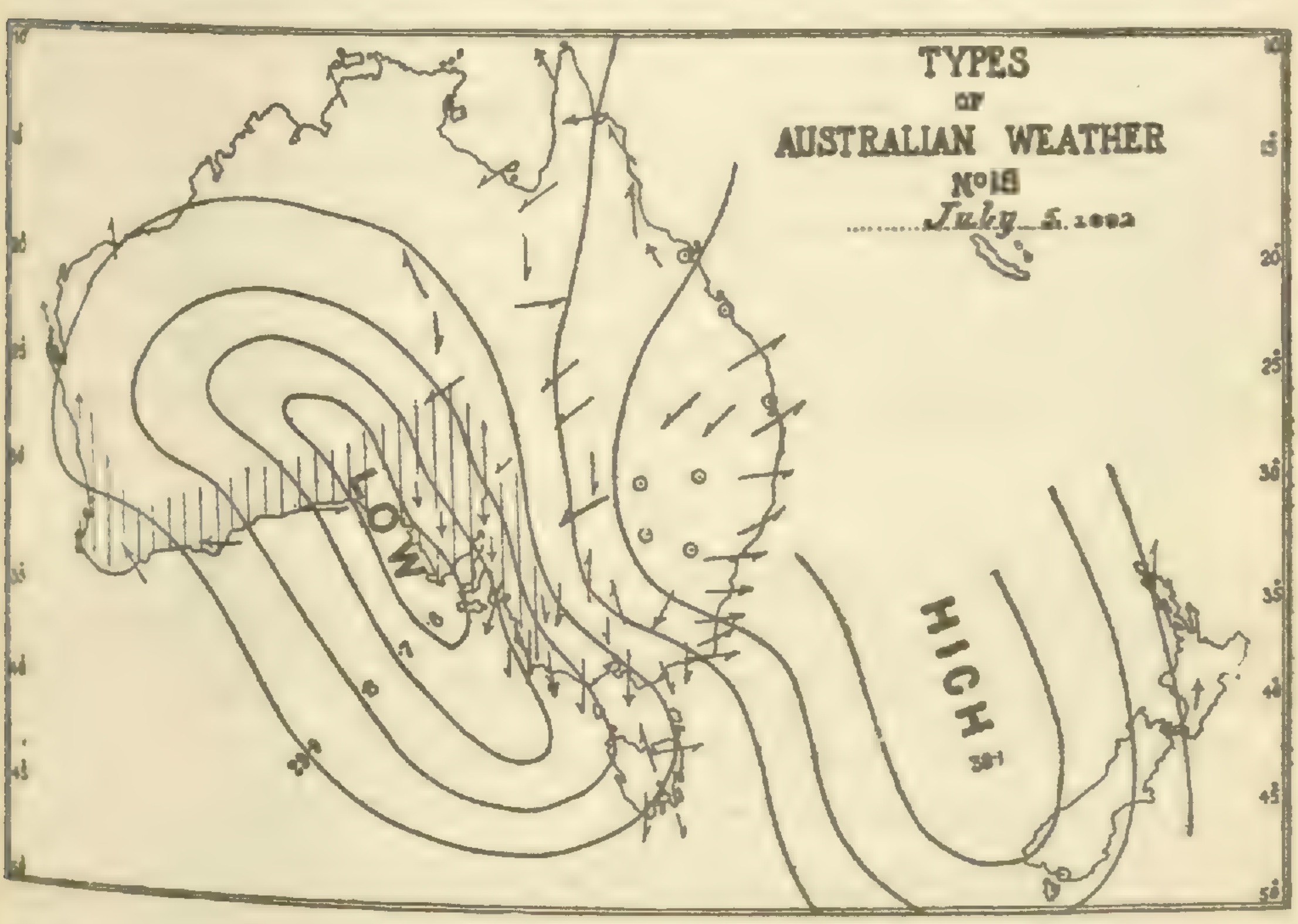
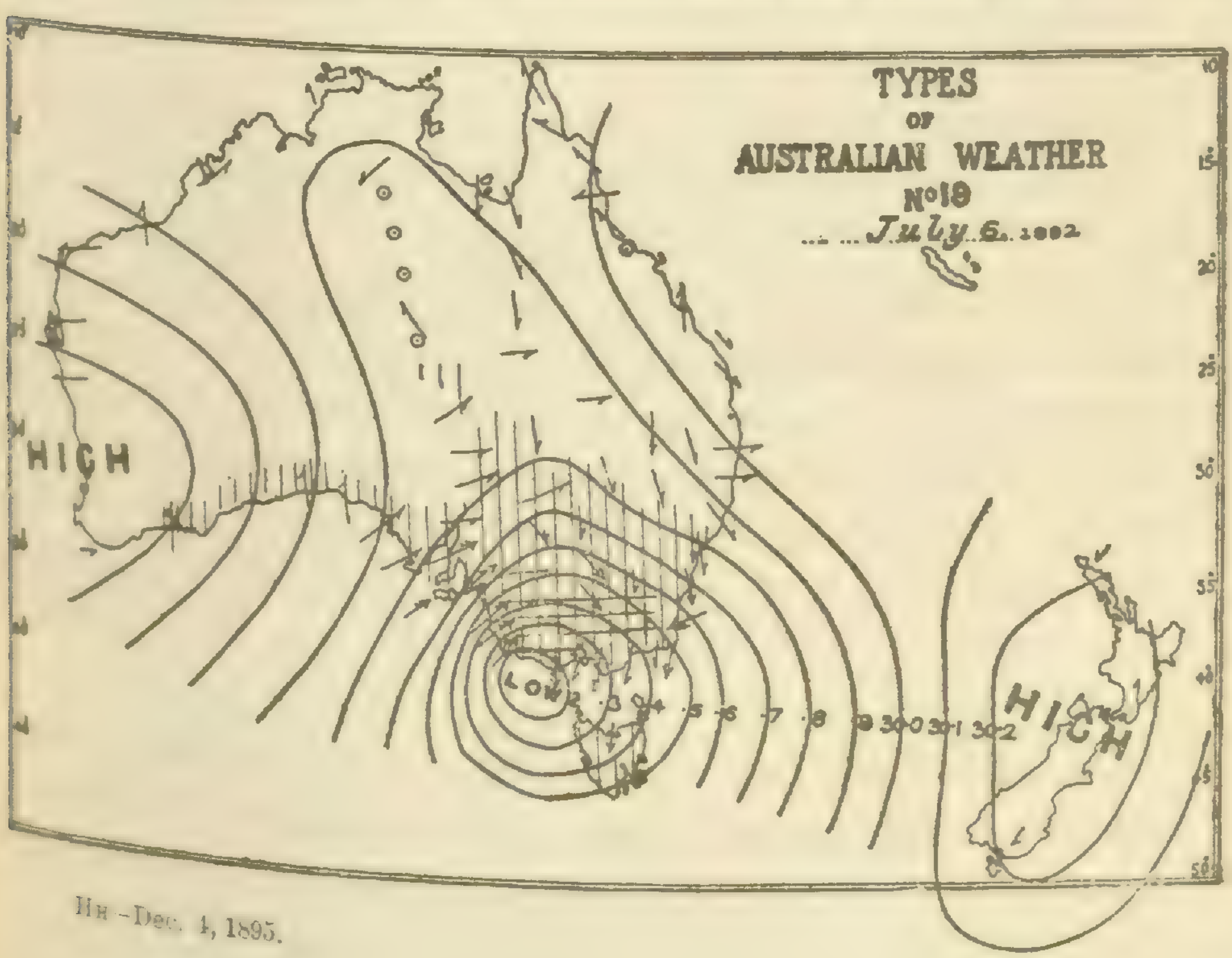


Chart 18, July 5th, shows that the whole system has moved rapidly, that the cyclone now with an elongated centre lying north-west to south-east now rests over South Australia, strong winds are rapidly developing, and the barometric grade about the





Hh—Dec. 4, 1895.

centre is much steeper, and rain has fallen over the south coast generally and extended northwards almost to Central Australia.

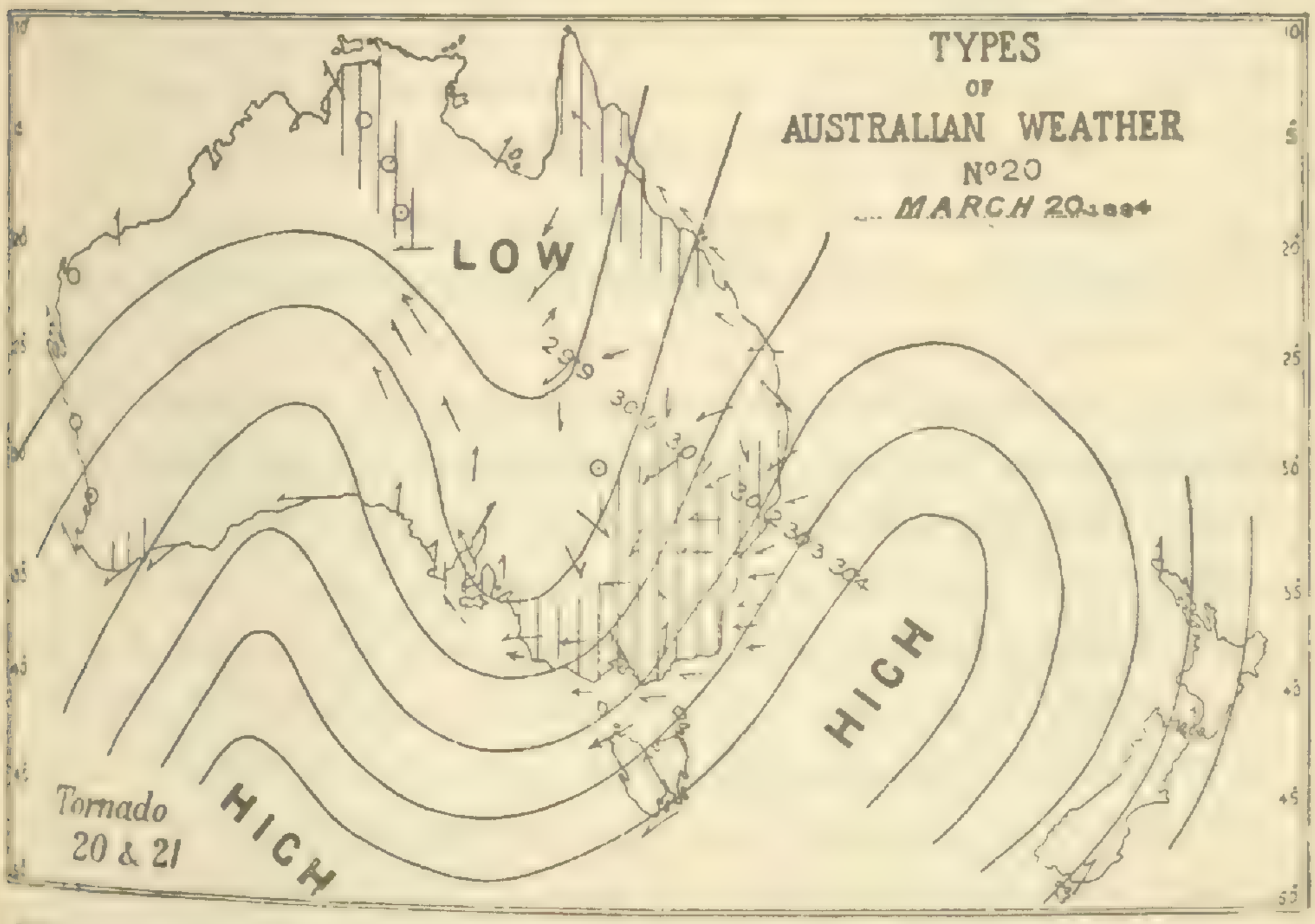
On July 6th at 9 a.m. the weather chart presented the features shown in Chart 19. The cyclone has intensified all round, and has moved rapidly to the east, its centre is just entering Bass' Straits; very heavy gales from south-west are blowing in the rear of the centre; heavy rain is falling over Victoria and extends over the greater part of New South Wales. All the winds controlled by this storm were very heavy, and during the 6th July, as the storm passed through Bass' Straits, extremely heavy weather was experienced there. On July 7th it had filled up.

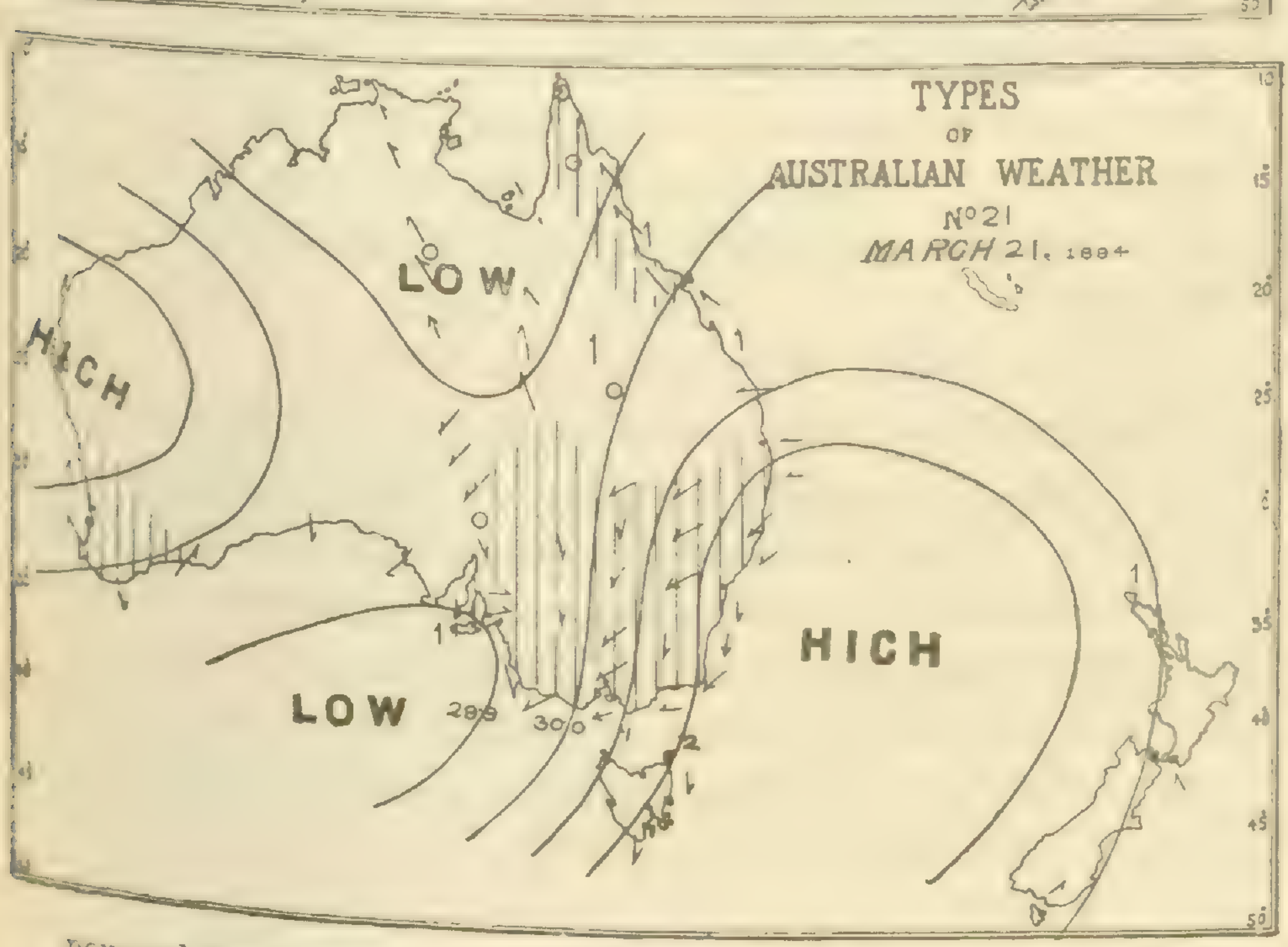
TYPE IX.—TORNADOES.

These occur during the summer months, and are most frequent in the western plains; they are developed in hot weather and in the low pressure known as a "Col" between two high pressures, when there is not enough grade to control the winds and the heating power of the sun is great; if to these there is added the presence of moisture from recent showers, we have all the conditions for the formation of a tornado. The force of wind is often sufficient to break off growing trees, two and even three feet in diameter, and the reason there is so little damage to life and property is not the want of power, but the sparse population and the very small number of towns.

Chart 20, March 20th, 1894. An extensive anticyclone lies south of Australia, giving way in its central parts to an extensive monsoonal dip. The isobars are generally uniform and of even gradients, though a suspicious interval exists to the west of New South Wales between the 30·0 and 29·9 curves. This is undoubtedly the area in which the secondary developed. Light rains were recorded in New South Wales and Victoria, but in Central Australia temperatures were high.

Chart 21, March 21st. A marvellous change has taken place. The area of high pressure on the previous day over the Tasman Sea has lost two-tenths in pressure. The monsoonal dip so pro-





nounced then has retreated, and is now only represented by one isobar, and where the western portion of the anticyclone existed on the 20th, an antarctic depression has protruded itself, and lastly an anticyclone is entering Western Australia. Thus a most favourable and extensive col area exists between these four systems

for the generation of these storms. The winds are generally blowing any way, and excepting those of the eastern high pressure have apparently no circulating power.

These were the conditions at 9 a.m., but as the day advanced the col area advanced with its arid heat, and this acting upon the precipitated moisture of the previous two days, resulted in the tornado which we are about to describe, and which occured at Bourke on the morning of March 21st, being one of the most terrific ever witnessed in that district. It struck the town at 10 o'clock, but could be seen approaching for some time from a north-westerly direction. It only lasted six minutes, but during that period thirty-nine points of rain fell, and several hundred pounds' worth of damage was done to houses. Chimneys, verandahs, trees, etc., suffered and general consternation prevailed. Many narrow escapes occurred, as the cyclone came across the common from the direction of Fort Bourke. The theatre was unroofed and a quantity of beams and iron was deposited in an adjoining yard. Pleasure boats on the river were sunk, and a steam-boat was considerably damaged by the falling of a large gum tree.

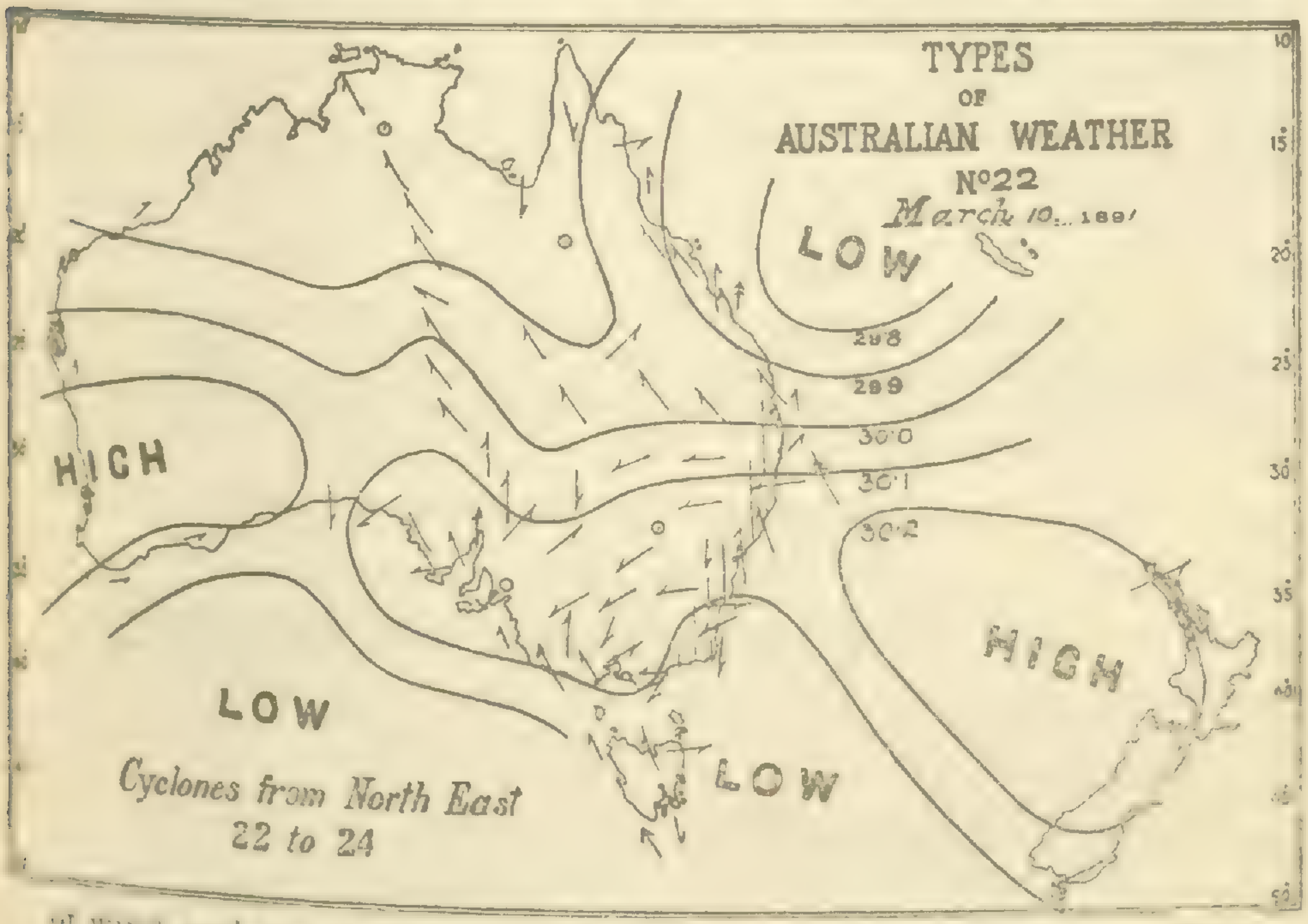
TYPE X.—CYCLONES FROM NORTH-EAST.

A comparatively small number of these storms reach the coast of Australia, and owing to the almost complete absence of observing stations, New Caledonia excepted, and the small number of vessels passing their tracks, it is usually impossible to trace their course before they reach Australia, but there seems to be no reason to doubt that they are more or less spent tropical cyclones, which reach Australia in the act of recurving. The majority reach the coast of Queensland between latitudes 20° and 26°; some farther north and south; only one has been traced from the coast inland and then recurving there to south-east. It reached the coast in the neighbourhood of Brisbane in January 1893, passed inland over the mountains, gradually curving to south past Mudgee to Dubbo, thence curving easterly it left the mainland about lat. 35° S. Its course was marked by violent cyclonic wind and rain

Picton reported 4·76″ rain. It has not been possible to present this as an example, because one of the days was a Sunday when very few observations are recorded.

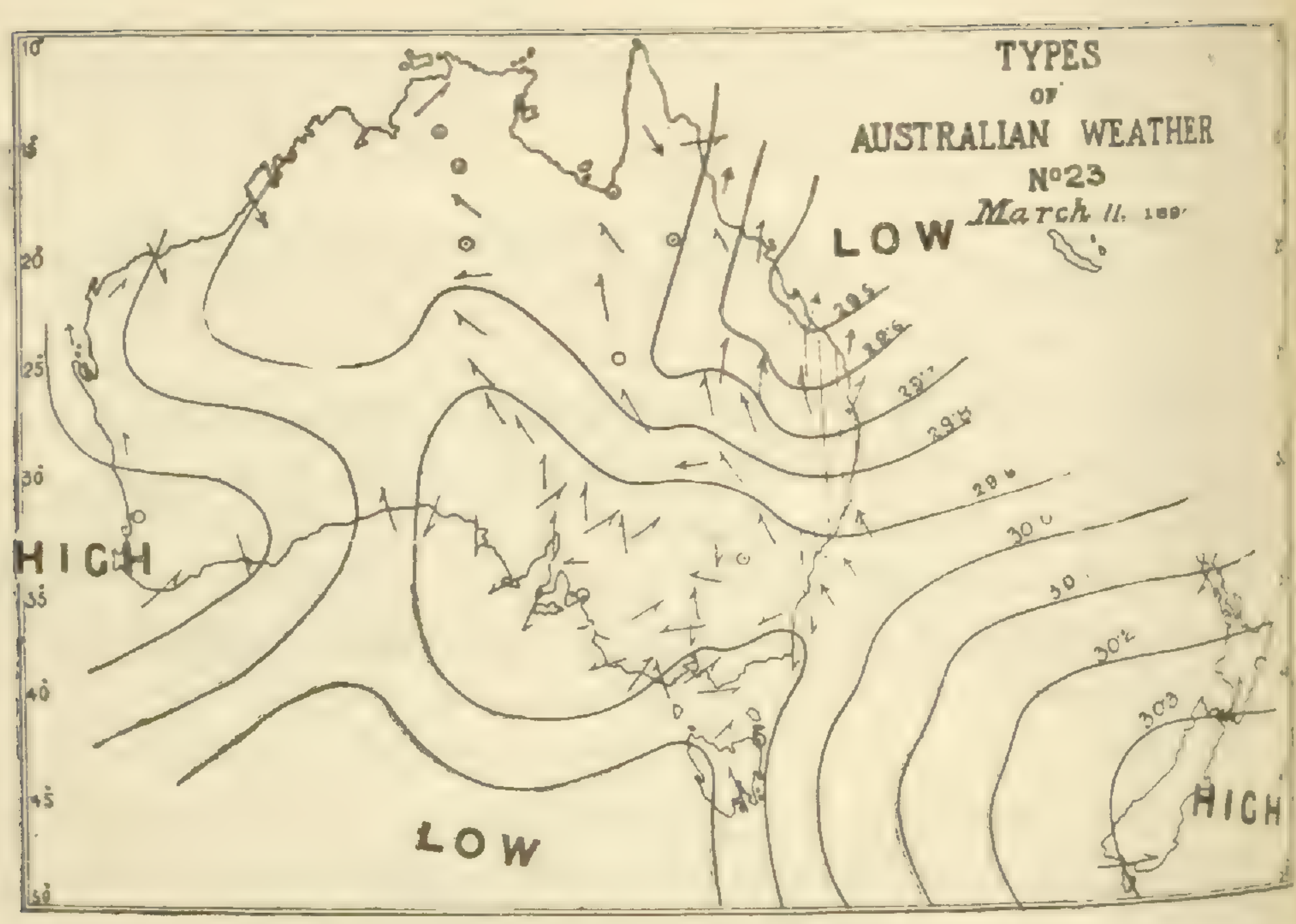
As a rule these north-east cyclones recurve at the coast line. Charts 22 and 23 show the weather conditions on March 10th and 11th, 1891.

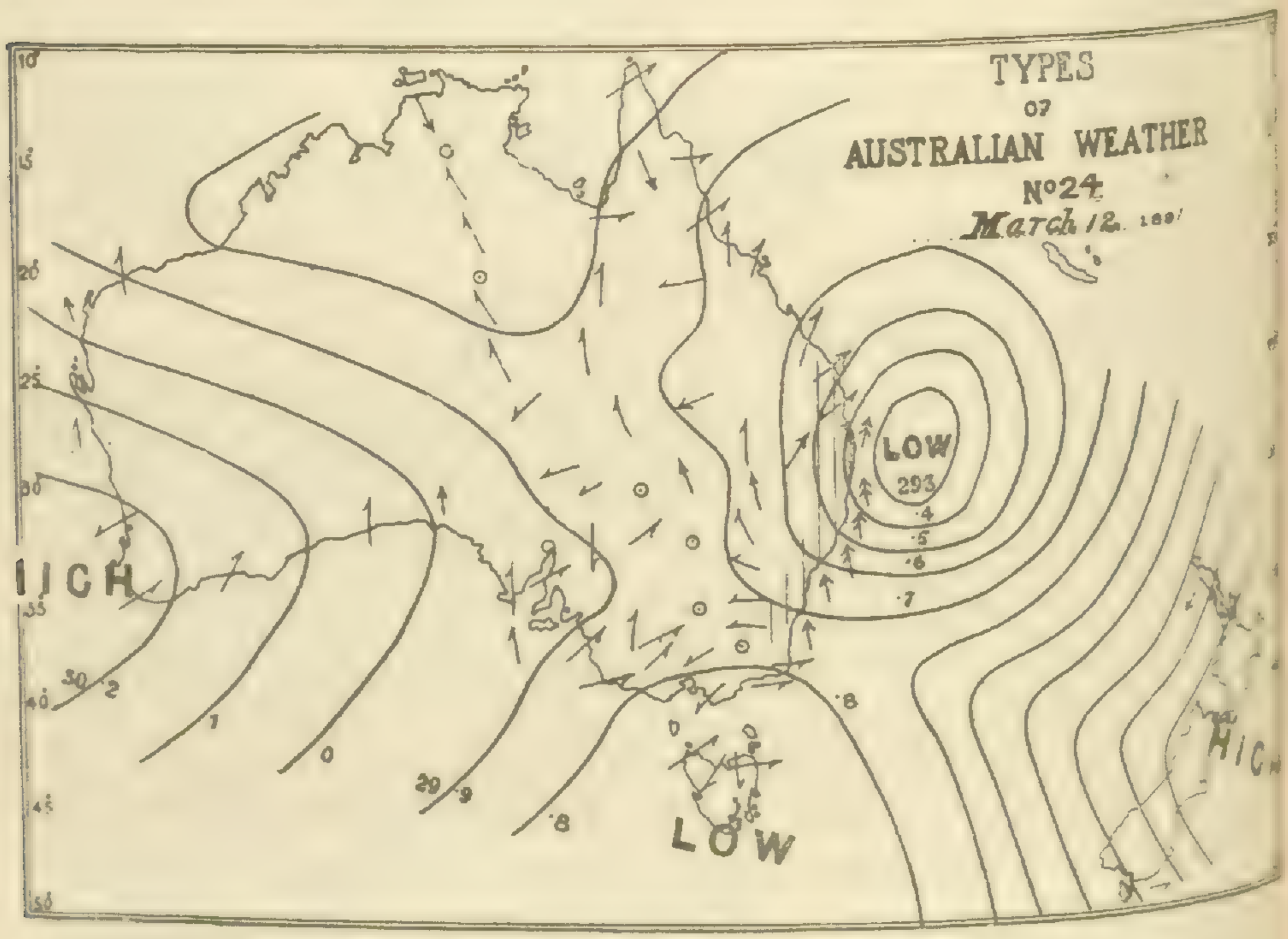
On March 10th there was a sudden fall of pressure on the coast of Queensland, about latitude 24° (Chart 22), and an accession



of wind and sea which clearly heralded the coming storm. This was intensified on March 11th, (Chart 23) by a further fall of three-tenths of an inch, and three more isobars of the cyclone were marked on the coast south to south-east; gales prevailed in its neighbourhood with very heavy rains.

On March 12th, (Chart 24) the anticyclone had retreated to New Zealand, and the cyclone travelled to the south along the coast intensifying as it came. The barometer curve at Brisbane was exactly of the cyclone type and dropped to 29·5. In the southern part of Queensland and northern of New South Wales heavy southerly to easterly gales were experienced. On the 13th the storm had disappeared to the eastward.





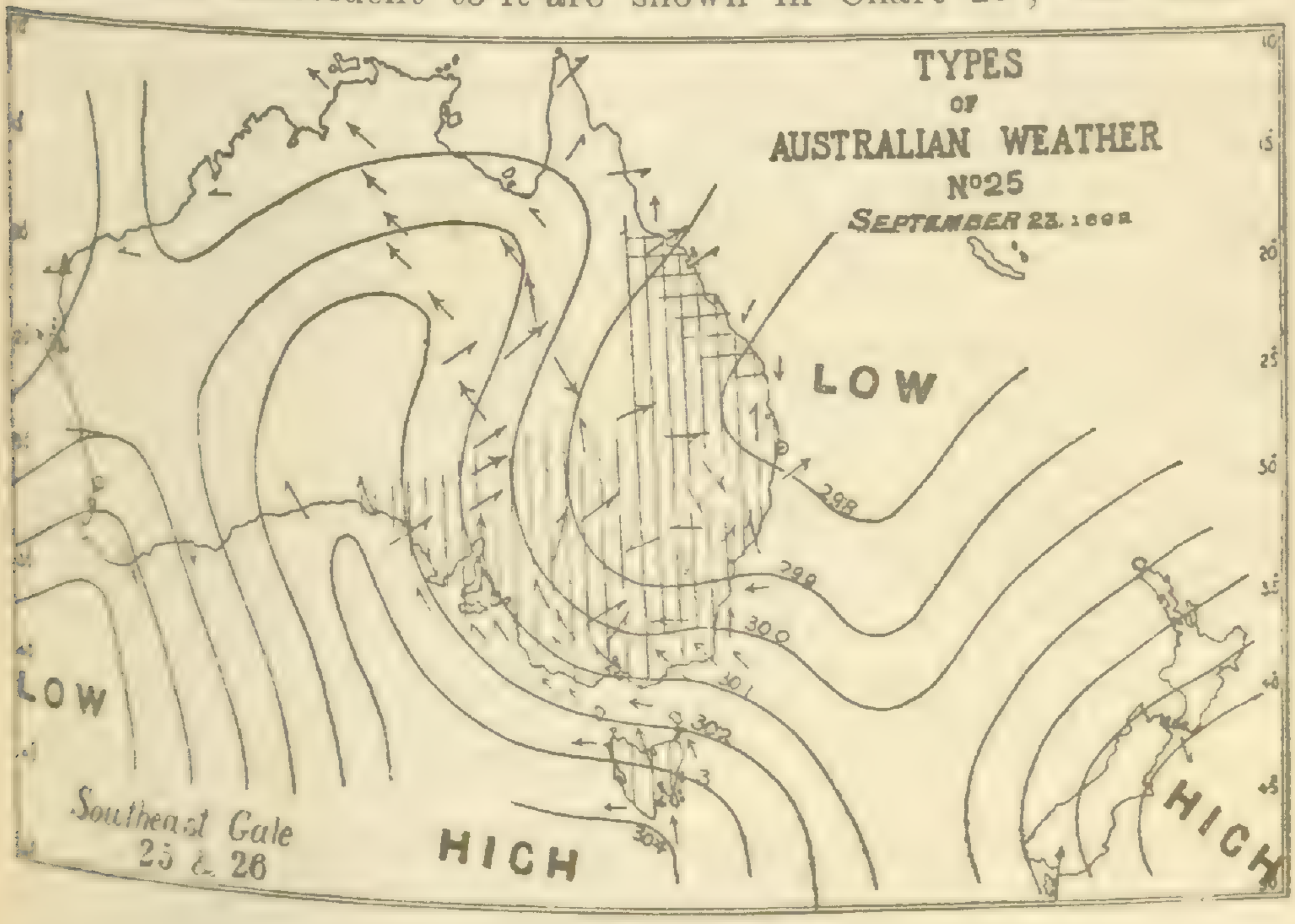
TYPE XI.—SOUTH-EAST GALES.

The south-east gale here referred to is peculiar to the east coast of Australia, and it has been responsible for the most memorable

wrecks on this coast. For the most part these gales appear to be partially spent cyclones, which come in from north-east or east, and travel down the coast until they begin to recurve to the eastward.

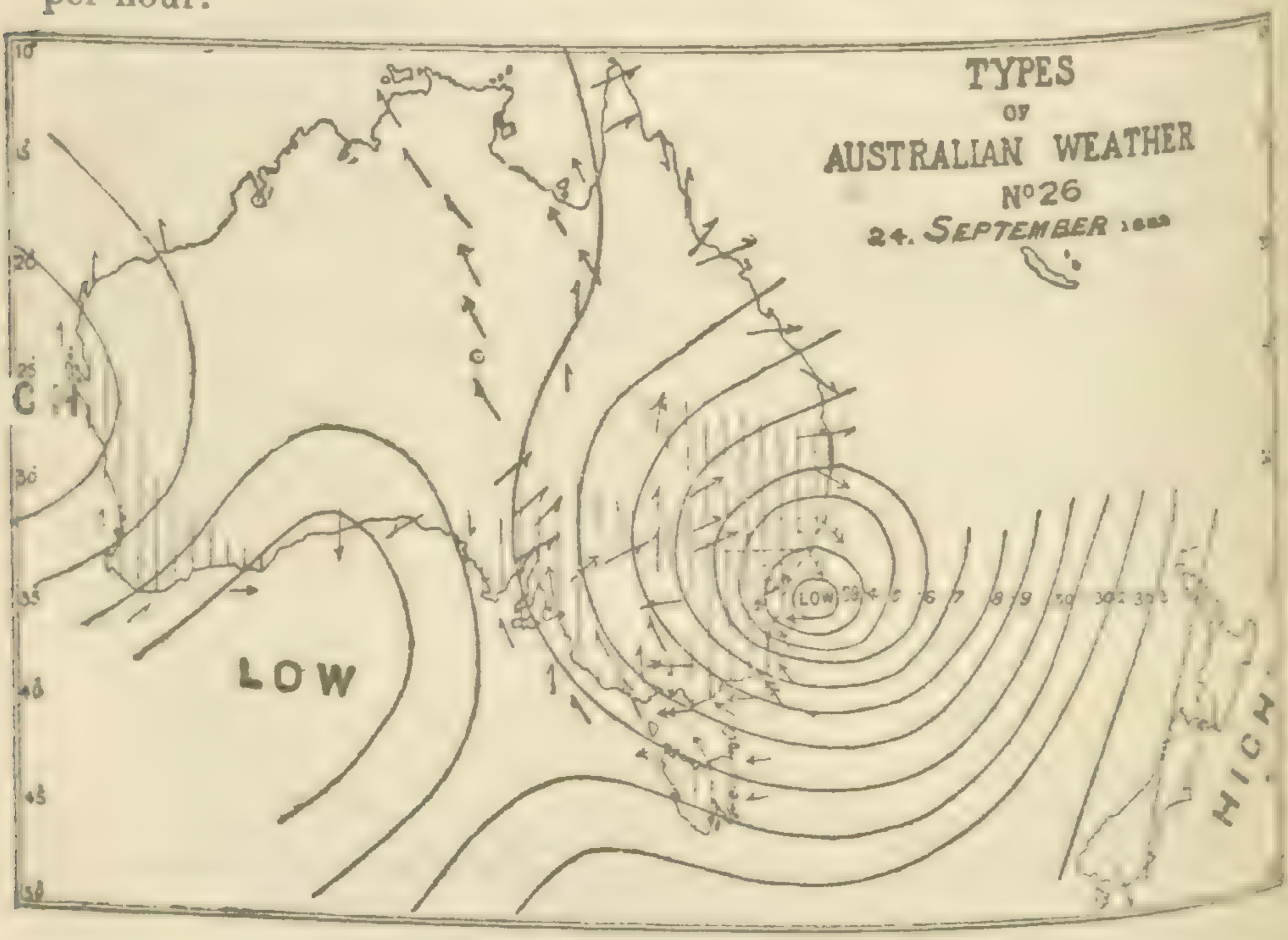
The warning of their coming is usually very short; it consists of a sudden increase in the sea on some northern part of the coast with wind from east to south, and falling barometers, while the high pressure over Victoria and South Australia becomes intensified and progresses into the Tasman Sea. The south-east circulation about this anticyclone increases in force with the increasing barometric grade, and also by the wind circulation about the cyclone, and the effect of the two causes acting together is to produce a most serious gale. Rarely, these storms originate in a monsoonal depression somewhere over South Australia, which travelling eastward intensifies on the east coast. Heavy rain is a marked feature of these storms, but it is confined to the coast, and rarely if ever extends inland.

The storm selected to illustrate this type was a very severe one, and began on September 23rd, 1892, about 6 p.m. The barometric conditions antecedent to it are shown in Chart 25; the main



features being the bend in the high pressure isobars, and the dormant low pressure off the coast of Queensland.

At 9 a.m. on this day there was nothing in the local weather conditions which would lead one to anticipate the gale that eventuated, the winds being generally light, and at Sydney only a light breeze was blowing from the South-south-west; but at 3 p.m. an unusual fall took place in the barometers to the north-east of New South Wales, and the winds there were freshening generally. On preparing a chart at this hour we found the depression was intensifying and had a cyclonic tendency; at 6 p.m. in Sydney the wind, which had been blowing from the south-east and gradually increasing in velocity, reached the force of a gale, a thick driving rain began to fall, which continued with little intermission until daybreak next day, when over 2″ were registered, and an extensive area around the metropolis benefitted to the extent of an inch and upwards; the barometer at this hour also began to fall rapidly and steadily, until at 5 a.m. on the 24th it read 29·203, and the wind had reached in one squall, lasting only a few seconds, the extraordinary rate of one hundred and twenty miles per hour, the mean rate of the gale being thirty-two miles per hour.



At 9 a.m. on the 24th, (Chart 26) the cyclone was still in an active state, but it had passed to the south of Sydney and was receding from the coast; the barometers were rising rapidly on shore, and before noon a light northerly wind was blowing. On the 25th September, the day following the gale, the weather everywhere was generally fine, while all that remained of the energetic high and low pressure systems were parallel isobars lying over the southern areas of Australia with very shallow gradients. This gale was very destructive and did much damage to property in Sydney; in some instances houses were unroofed, and the wind and sea on the coast were very heavy.

TYPE XII.—DEVELOPMENT OF A CYCLONE FROM A A DEPRESSION.

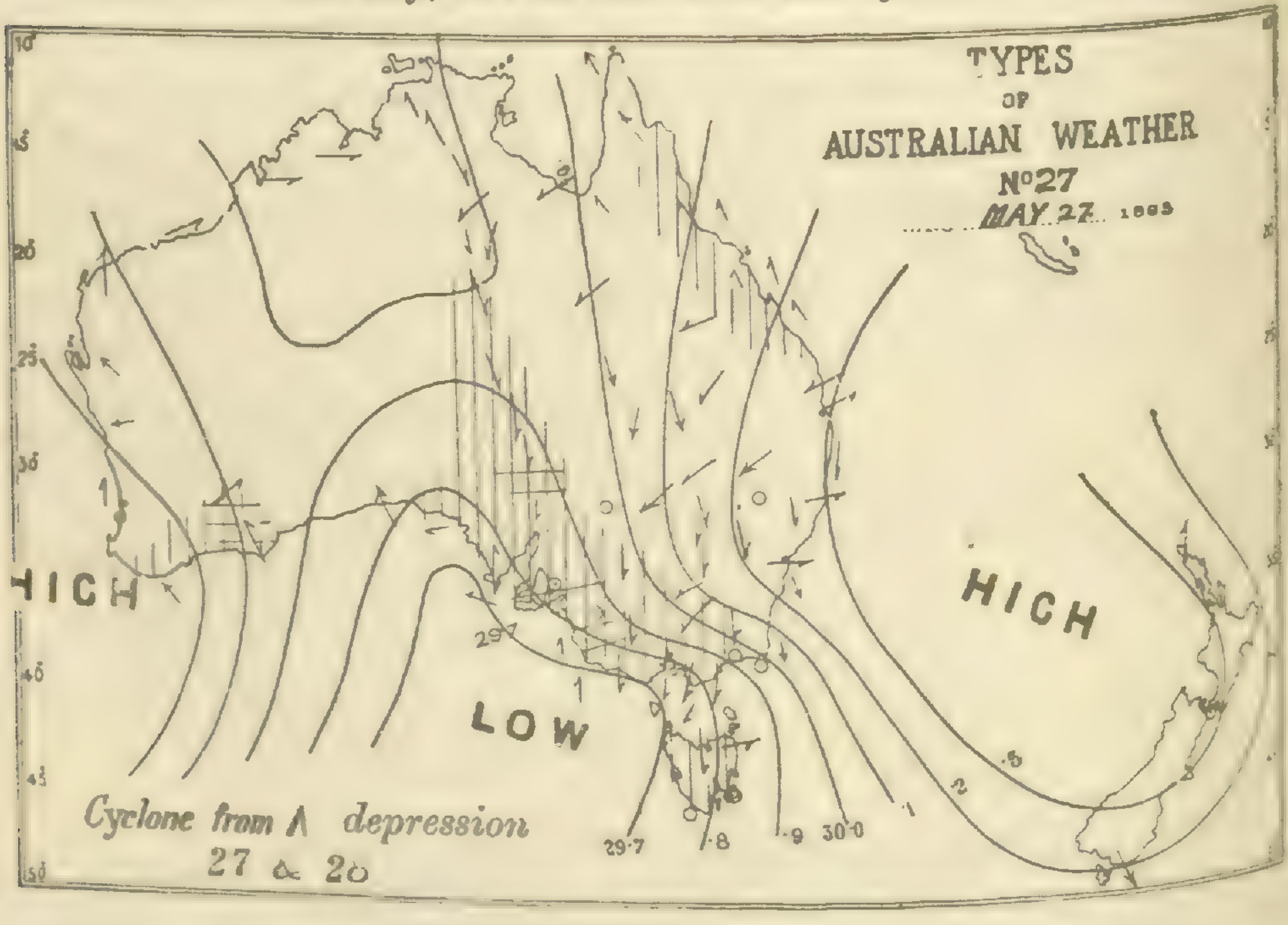
The distinction between a A depression and a monsoonal low pressure is not by any means well defined, and it is possible that this should be taken as a variation of Type 3; there are however, marked differences, not only in the shape of the isobars, but also in the wind; and the most decided distinction is perhaps the easterly wind circulating round the southern part of the monsoonal low pressure and the northerly and southerly winds about the A; but in some cases, as in the one selected, the wind circulation is mixed. northerly, southerly and easterly winds being present, and these from their want of energy tend to throw the forecaster off his guard. The season is, however, some guide, as these storms are most frequent from September to April.

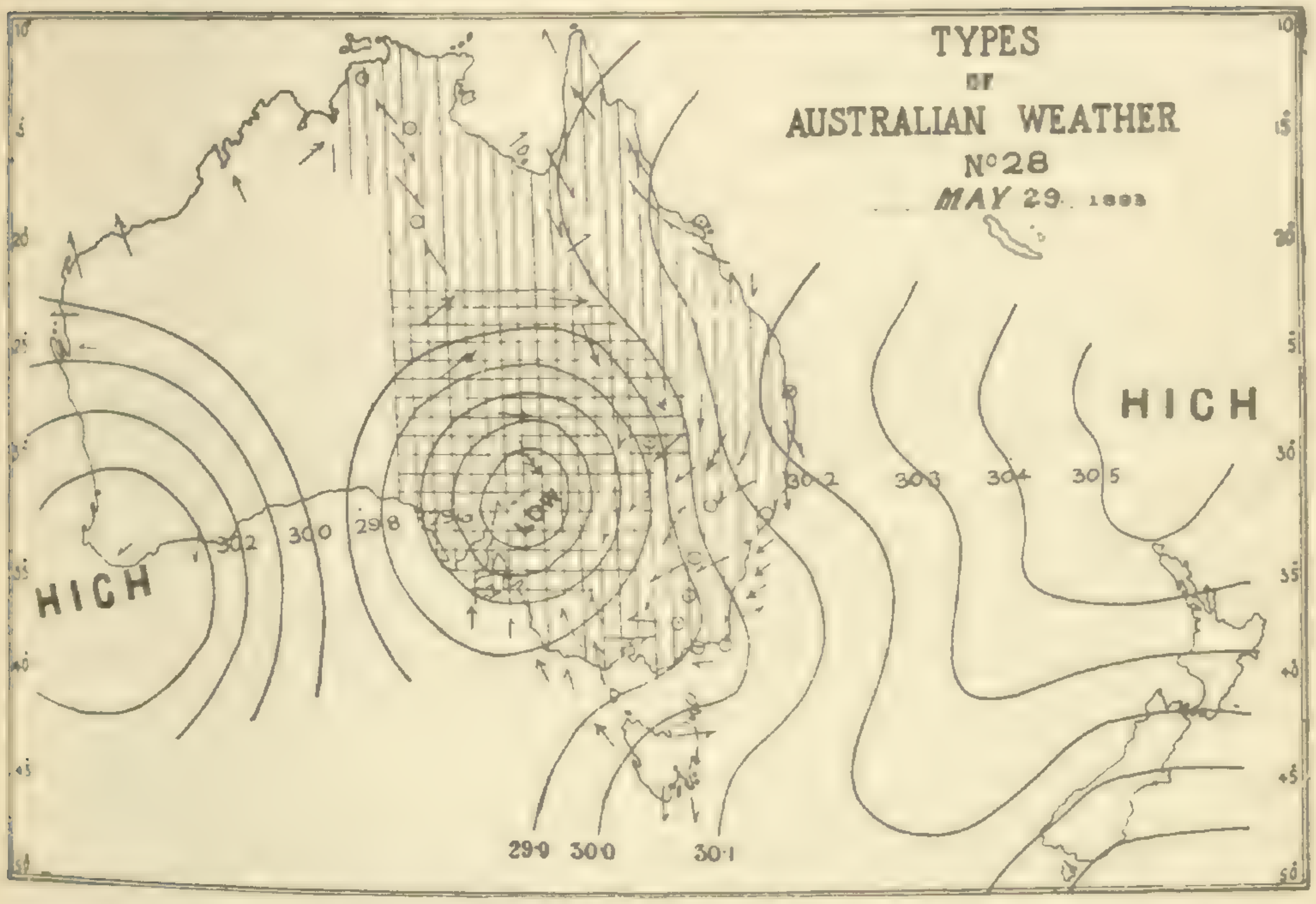
Their sphere of influence is very extensive, as may be noted in Chart 28, which shows rain over half Australia as the apparent result of this storm. Most of these storms take a direct easterly course over New South Wales and Victoria or through Bass' Straits. At times they move to north-east, the Polar winds being more energetic, and this feature intensifies all the storm and rain conditions. The winds in all these storms are violent, and in some very destructive.

The one selected for illustration appeared first on 27th May, 1913, (Chart 27). At 9 a.m. on that day, a dormant and irregular

A depression existed over the Australian Bight, the winds were moderate northerly and southerly, as usual in such conditions, there were a few light easterly winds. Isobars were close over eastern Victoria, but there was nothing which seemed to indicate the violent cyclone that developed during that day over southern parts of South Australia and south-west of New South Wales. (See Charts 27 and 28.) This storm formed in the rear of a very substantial anticyclone, then over the Tasman Sea, and it should be noted that it did not act as a secondary and travel round the southern and eastern parts of the high pressure, but it moved towards the northern side of it and against its circulation, thus proving its own Polar impulse and energy, and giving rise to very strong gales and steep barometric grades with great fall of temperatures; these conditions produced extremely heavy and wide spread rains, not only within the storm isobars, but over the whole of the eastern half of Australia. We have no means of tracing the rain to the west of the overland telegraph line, because there are no observing stations there.

May 28th was unfortunately a Sunday, and we have no observations for that day, but on the 29th the cyclone is seen in full





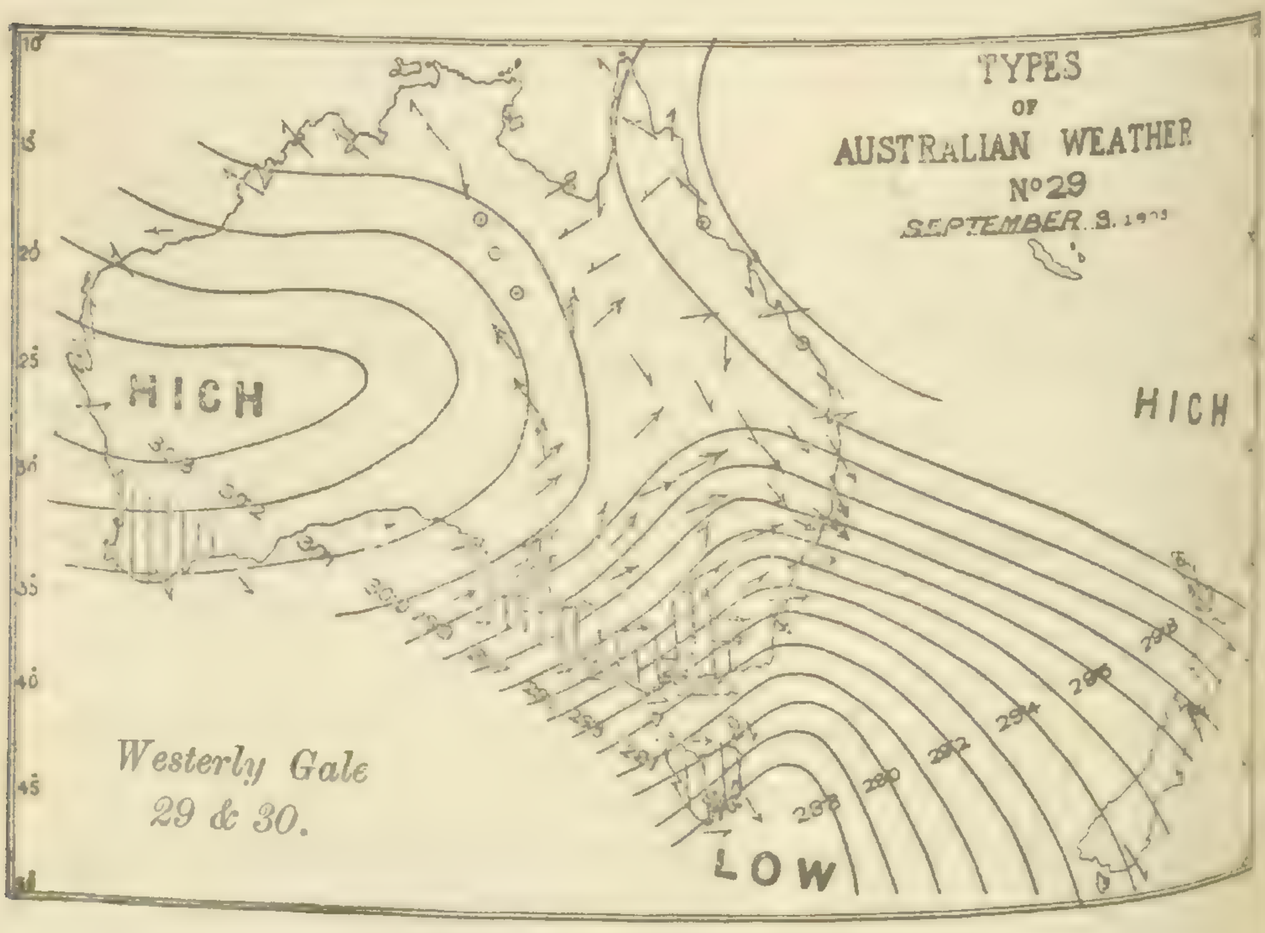
strength covering the southern colonies of South Australia and Victoria, and the greater part of New South Wales; its isobars are unusually symmetrical and its rain influence the most extensive we have on record. During the 29th and 30th rain continued to fall over considerable areas, although on the 30th the depression filled up and the storm was displaced by the high pressure coming on from the west.

TYPE XIII.—WESTERLY WINDS.

The Winter anticyclone (See Chart 36) is much nore extensive than the Summer one, and its grades are steeper and circulation stronger, while its latitude is further north, often up to 30° S.; hence the circulation on its southern side, unlike the Summer one, affects the mainland of Australia and gives us our westerly winds. And just as the trade wind intensifies its northern circulation by adding force thereto, so the brave west winds of the southern ocean follow the general move of the weather systems northwards, and thus add force to the westerly circulation of the anticyclone, and its greater dimensions increase the size of the \ depression, so much that it no longer has the sharply defined change from

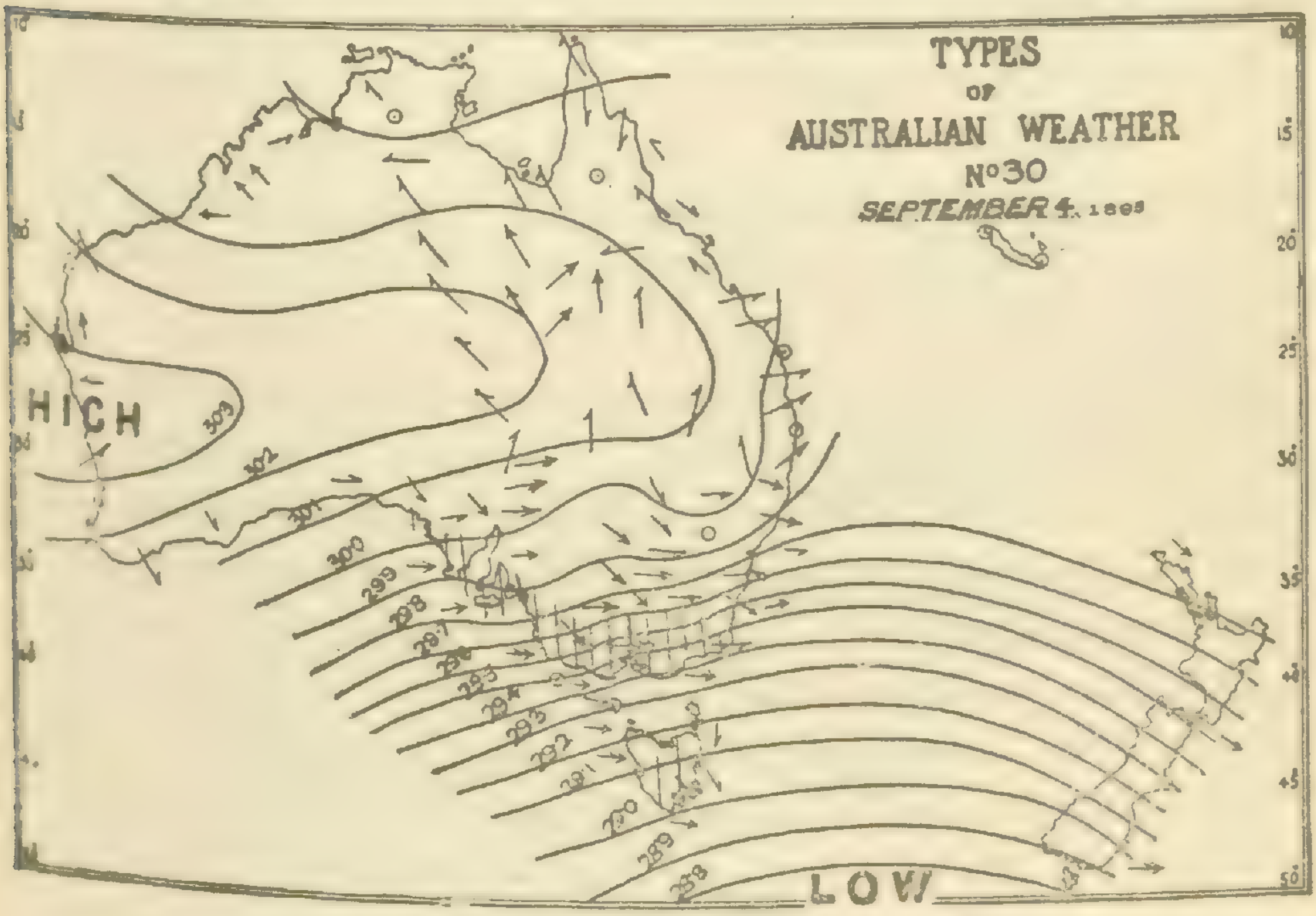
notherly to southerly winds, but from north-west to south-west winds; all these conditions combine to strengthen the westerly circulation, until at times they seem to be like the brave west winds of the roaring forties.

On the east coast they extend further north than they do inland, and at times include Brisbane within their influence. When very strong the anticyclone is elongated and the southern isobars are flattened. (See Chart 30). They are very cold and dry, having all the raw feeling of the easterly winds of England, and have been known to last for several weeks without intermission; they are the most persistent winds during our winter. In heavy westerly winds the cold is very severe in Bass' Straits, between the south coast of Victoria and Tasmania, rain, hail, and sleet being very common. It is almost needless to say that on land they bring very little rain, and they rapidly dry up the soil. The severe drought of 1895 was largely due to the persistent westerly winds which rapidly dried up the occasional rains; this feature becomes intensified if instead of coming from due west they blow from north-west.



Turning now to the charts of the westerly gale selected for illustration, it will be seen in Chart 29, that this storm began on September 3rd, 1895; on that day an elongated anticyclone lay over Western Australia, a flattened and extensive ∧ over New South Wales and Tasman Sea, and the winds generally displayed great energy, as might be expected from the close isobars, and unusually low barometers over Tasmania; light rain was falling on the coasts of South Australia and Victoria.

On September 4th, Chart 30, the anticyclone is more elongated and the ∧ flattened until its isobars are nearly horizontal, and heavy westerly gales swept all the south-eastern part of Australia and all Tasmania. On the 3rd the wind at Sydney at noon for a short time reached a velocity of seventy-eight miles per hour. On the 4th the wind was less gusty, but its average velocity was quite as strong as it was on the 3rd.



TYPE XIV.—SOUTHERLY BURSTERS.

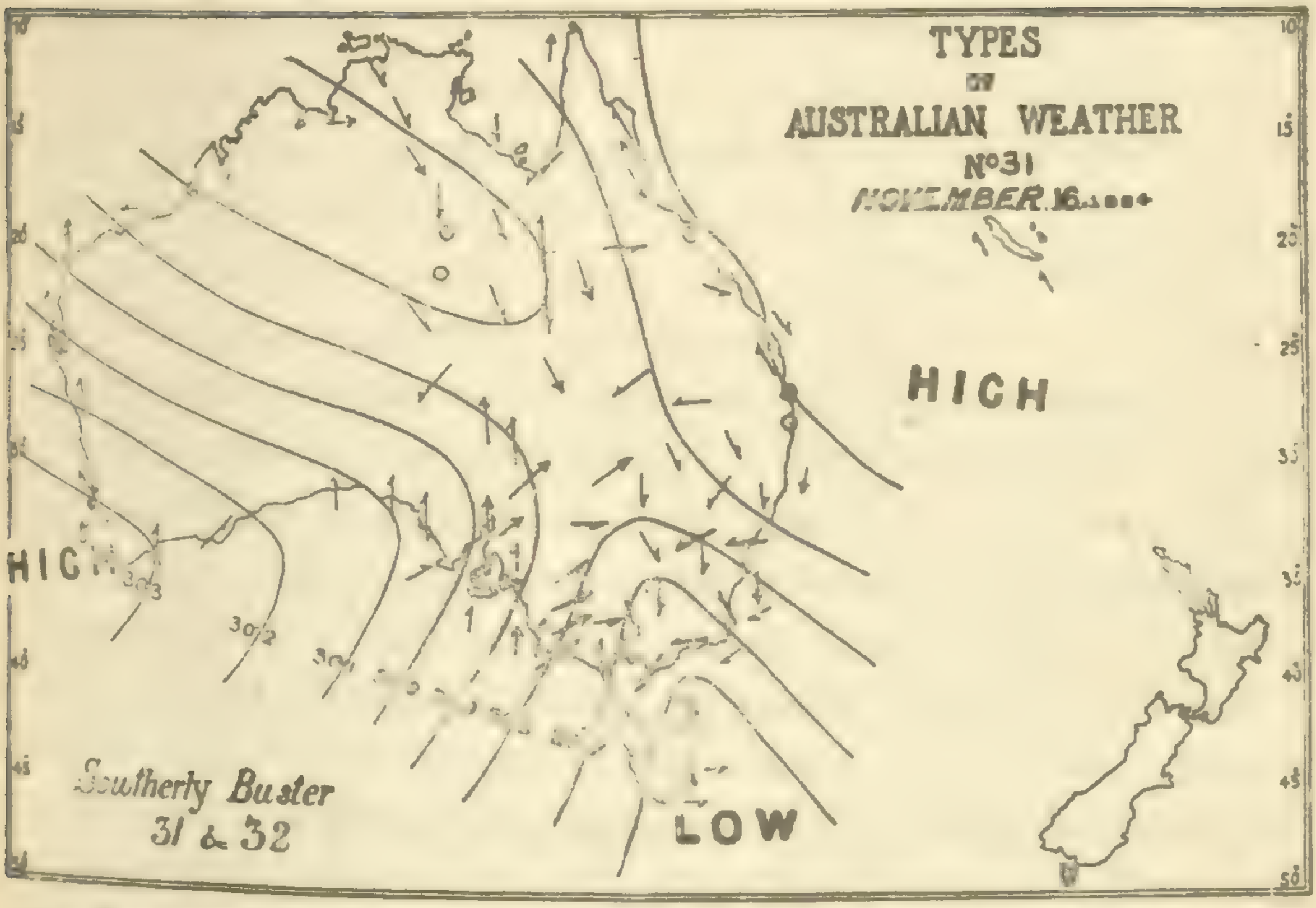
The southerly burster is a well known feature or type of Australian weather, so well marked in character indeed that it requires no special training in meteorology to recognise it; its character-

istics are so obtrusive that they cannot be overlooked, and they are welcomed as the most pleasant relief after the high temperatures and oppressive northerly winds which precede them. They come in the late spring, all summer, and part of autumn, but as a rule, in order to get a strong southerly an antecedent excessively hot day or days must be experienced. The duration of a southerly burster may be anything from two hours to ten days, but it is not to be understood that the term burster is applied to the whole period or duration of the southerly wind. What is called a burster is the squall or sudden and violent change of wind direction, and the violent rush or "burst" which marks the advent of this wind. We need not go into all the characteristics; these will be found in the Abercromby Prize Essay on this subject.[1] It is there explained that the south wind comes in front of an approaching anticyclone, and that it is felt from West to Eastern Australia, but it is only on the eastern coast, where, aided by the smaller friction of the ocean and the shelter which the mountains afford from other winds, that the southerly becomes more vigorous and rushes northwards in a squall, which happens so suddenly and with such force, that at times ships drag their anchors in Sydney harbour.

It is not definitely made out yet that these storms are ever "line storms" in the sense that the change of wind comes as the dip in the isobars passes over each place in succession, but there are many facts which suggest that such is the fact in some instances. Our present purpose is to describe a "burster" as a type of Australian weather. The essential feature of it is a sharp A; in Chart 31 such a depression is shewn existing over Victoria and Tasmania, with its axis lying from north-north-west to south-south-east. An anticyclone of good energy for this time of the year exists to the west, and hot northerly winds occupy northern Australia; these are the elements for the good burster that followed. As a general rule,[2] the position and character of two

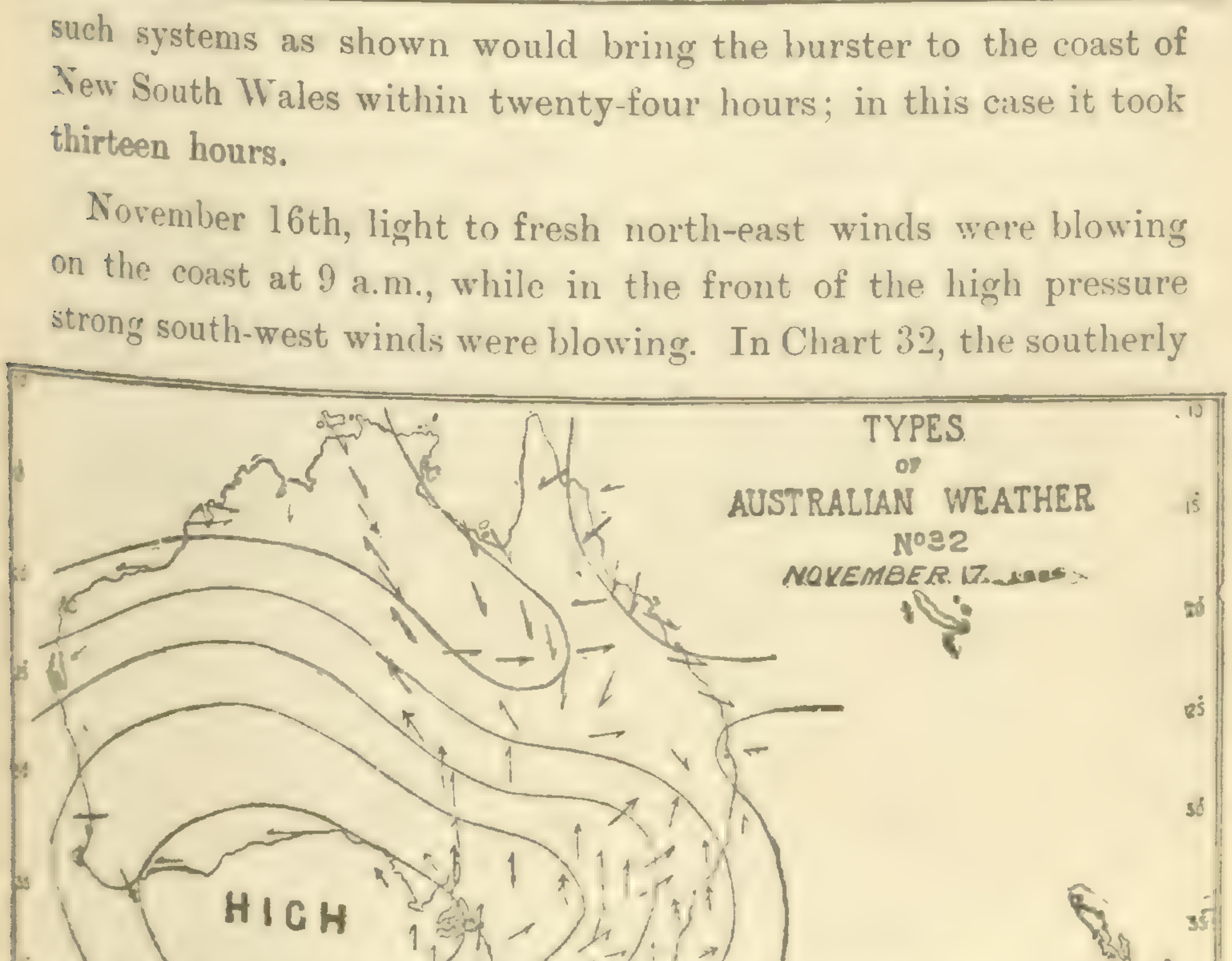
[1] Journal Royal Society, N. S. Wales, Vol. XXVIII.

[2] Moving Anticyclones—Quarterly Journal Roy. Met. Soc., Vol. XIX.



such systems as shown would bring the burster to the coast of New South Wales within twenty-four hours; in this case it took thirteen hours.

November 16th, light to fresh north-east winds were blowing on the coast at 9 a.m., while in the front of the high pressure strong south-west winds were blowing. In Chart 32, the southerly

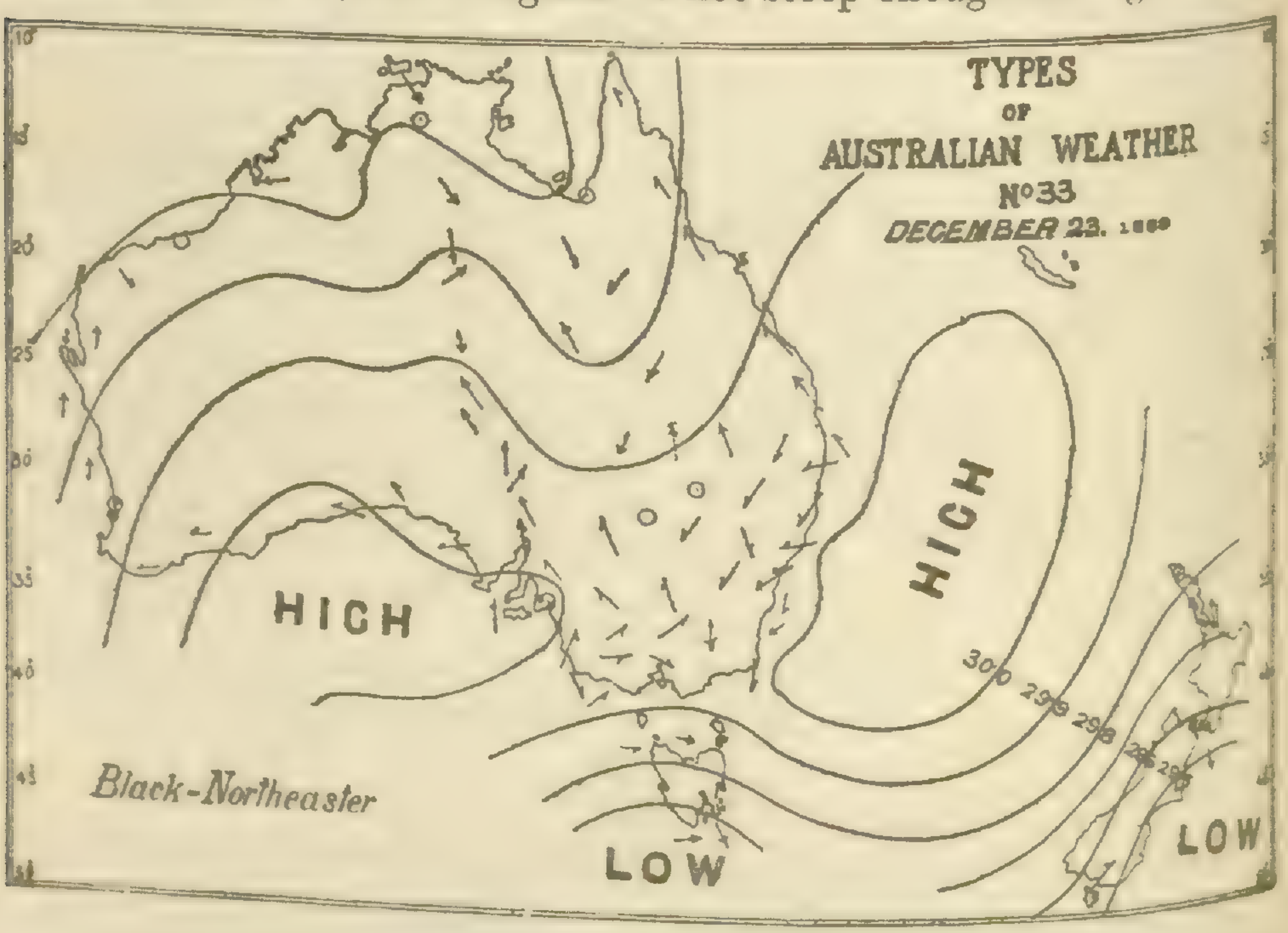


is shown in full force in front of the anticyclone, which by the way has lost none of its energy since the previous day; the depression is well off the coast and on its way to New Zealand. This burster reached a velocity of forty-nine miles per hour, and lasted thirty-five hours.

TYPE XV.—THE BLACK NORTH-EASTER.

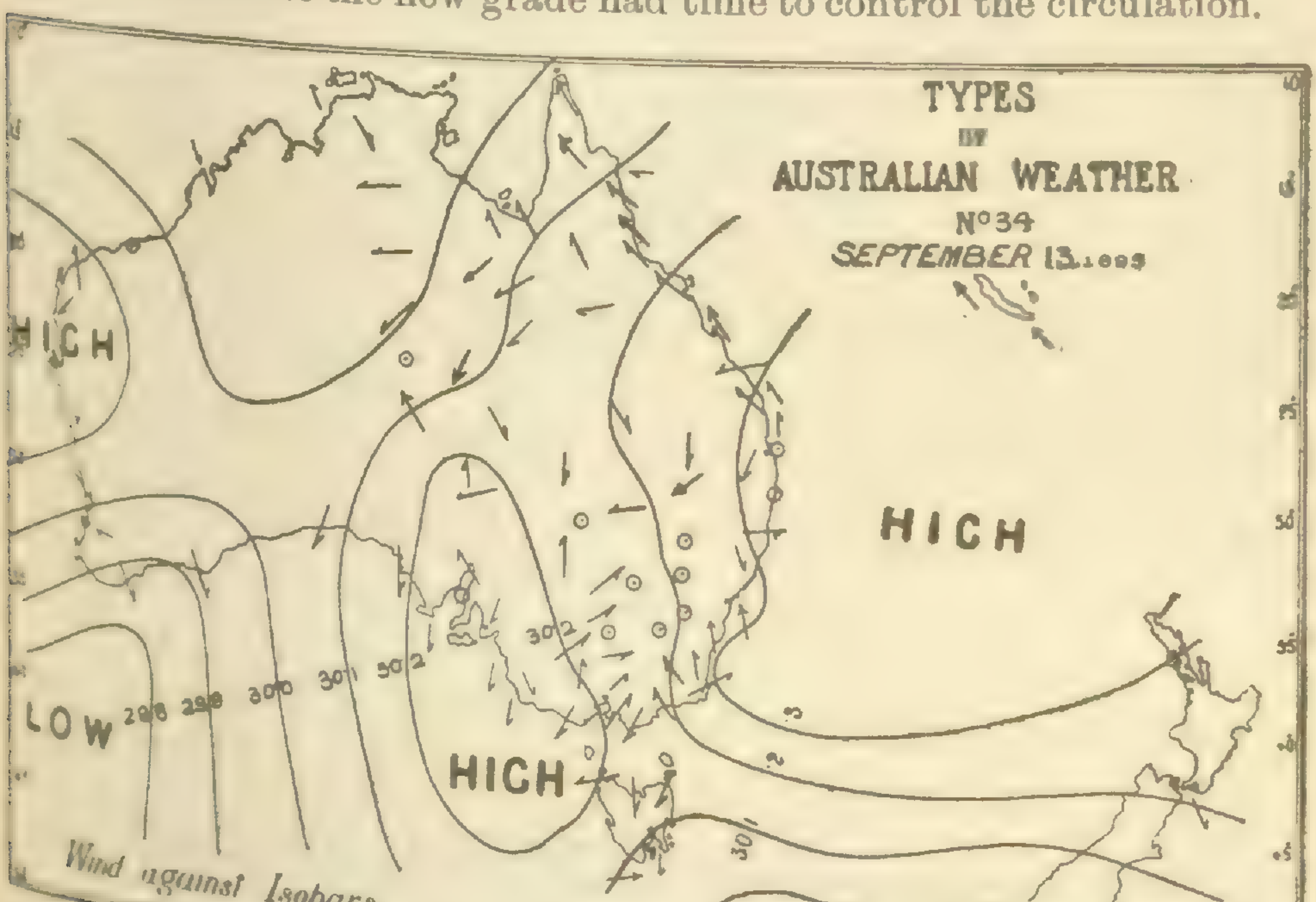
This is a somewhat uncommon but nevertheless well known type of weather on the coast about Sydney. Its characteristics are a very strong and persistent north-east gale, continuing day and night for two or more days; it has been known to last five days and nights, and it ends with the advent of a southerly burster. Its cause is found in an extensive col, the rear of one anticyclone being at rest over this coast, while another lies over the Australian Bight. If the grade is rather steep and the system at rest for several days, then the north-east wind persists with force proportionated to the grade, until the whole system moves forward; the southerly winds in the front of the approaching high pressure then displace the north-easter and the storm is over.

There have been no good examples of this type since weather charts have been printed here. Chart 33 shows the necessary forms of isobars, but the grade is not steep enough for a gale.



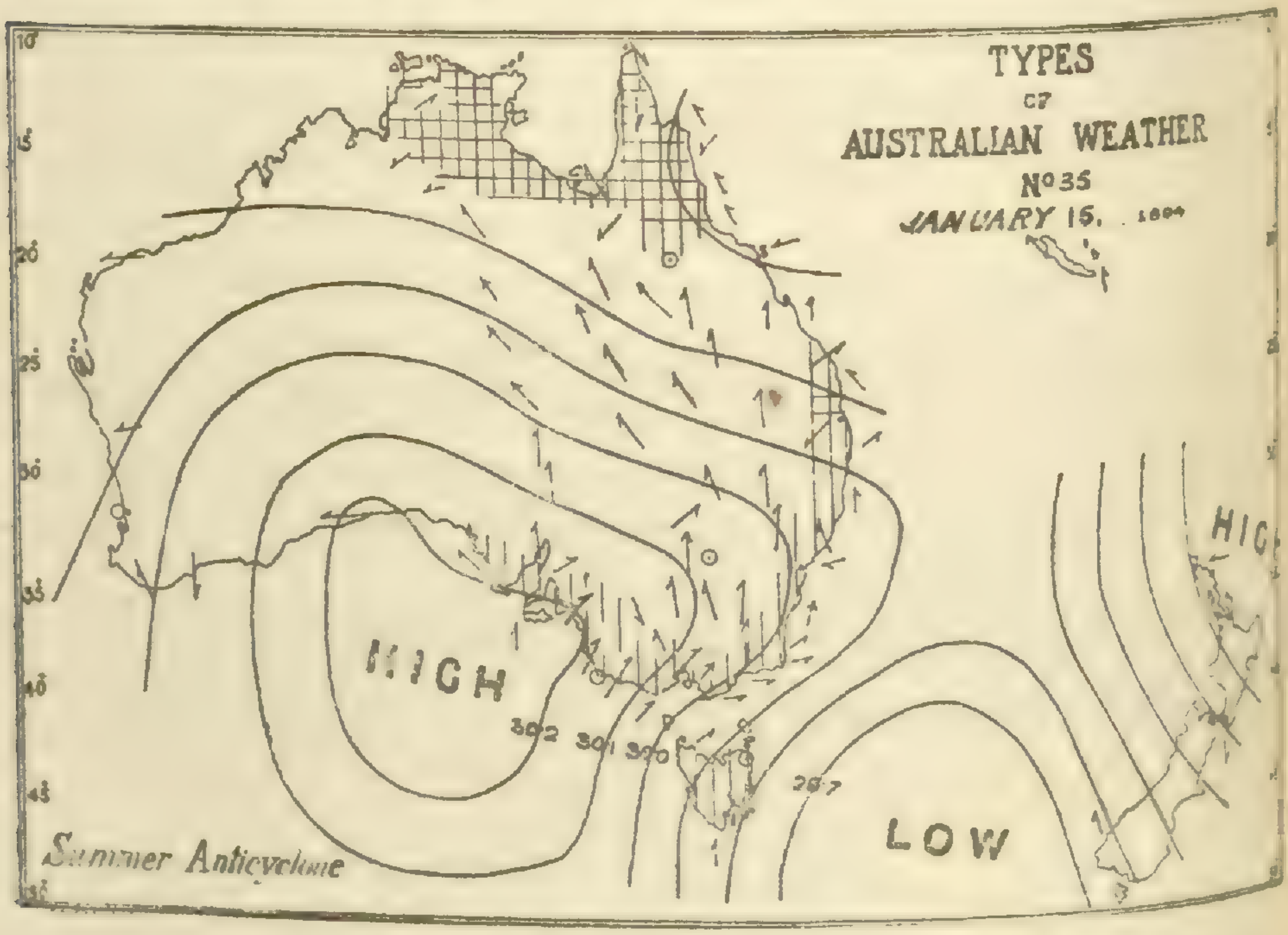
TYPE XVI.—WIND BLOWING CONTRARY TO ISOBARS.

In this type the wind blows with considerable force in a direction directly opposed to that which the isobars would lead us to expect. For instance in No. 34, it will be seen that an extensive high pressure rests over the east coast, and the isobars are comparatively close together. The normal circulation with these isobars would be fresh north to north-west winds, when, as a matter of fact, strong southerly winds were blowing as far as Sydney with a velocity of thirty miles per hour. Such conditions are rather troublesome in forecasting; fortunately they do not come often, and the fact is not confined to southerly winds. The general direction of the coast line is northerly bearing east a little, a range of mountains from two to four thousand feet high runs nearly paralled to it, and this local formation has a very important effect on the circulation of the wind; as in Chart 34 it seems to have more effect than the isobars, and probably the grade was rapidly intensifying and had not been long enough in existence to fully control the winds. It seems probable, so far as this type has been studied, that we should find that when the wind blows contrary to isobars, it does so because of some impulse given to it before the new grade had time to control the circulation.



TYPE XVII.—SUMMER ANTICYCLONES.

One of the most marked features of weather in Australia is the regular easterly motion of it in all seasons of the year, added to this the anticyclones—the controlling element in our weather—change with the sun, so that the latitude they follow in their easterly progress is further south in summer than in winter.[1] The summer latitude is about 40° south. They are less extensive in summer than in winter, and do not so completely control our weather as they do in winter, for their southern position leaves room for the southerly extension of monsoonal low pressures, which make a great deal of our weather; but the anticyclone makes the change from hot northerly to cool southerly winds, the bursters of the east coast.



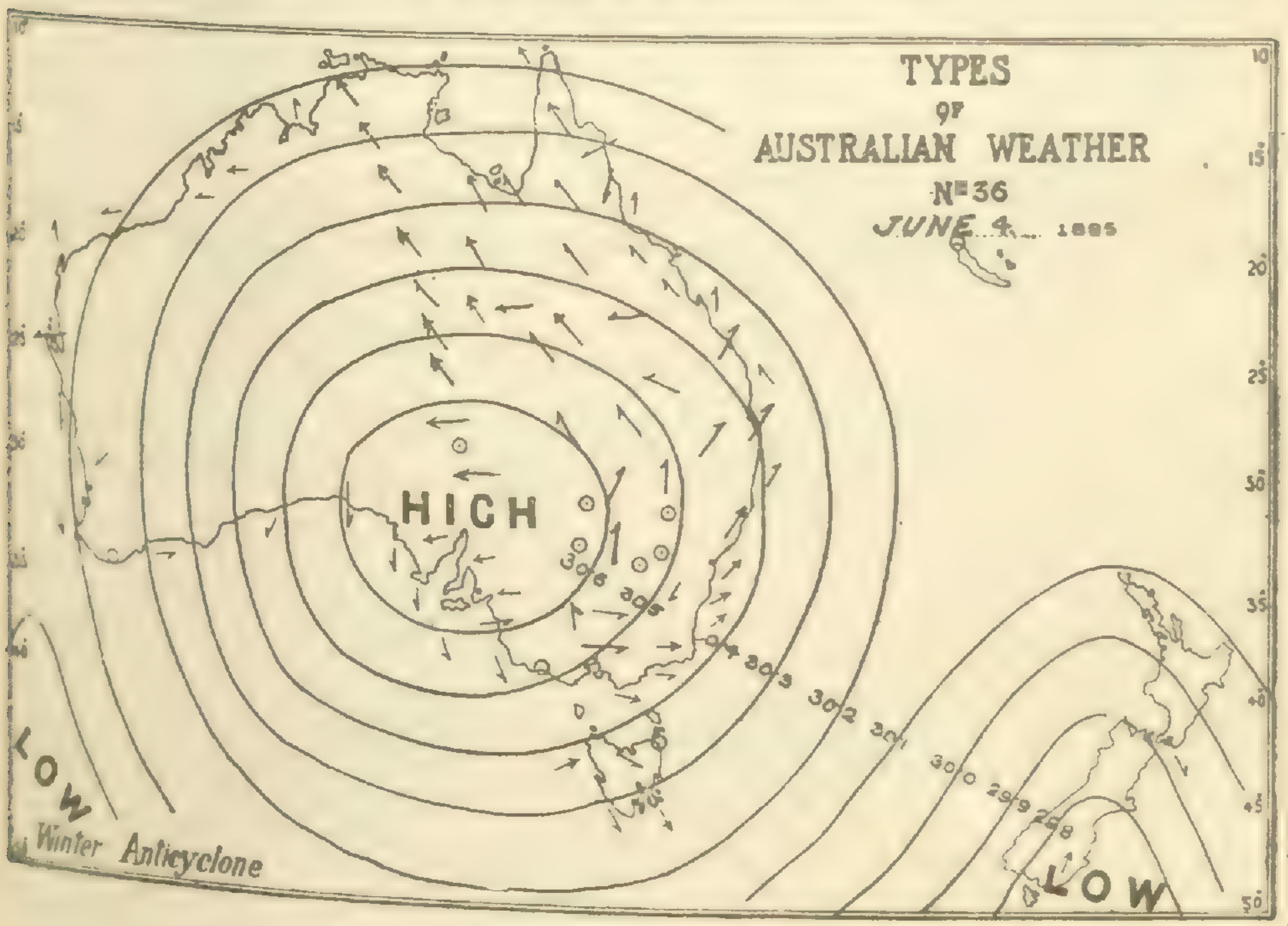
TYPE XVIII.—WINTER ANTICYCLONES.

During the winter months the antiyclones are much larger than they are in summer, and their latitude about 30° S.; very commonly their area is equal to Australia, and their control of the weather more complete than it is in summer. Fine weather

[1] Moving Anticyclones—Quart. Journ. R.M.S., No. 85, Jan. 1893.

marks their centres, and the rains come chiefly from the low pressures between each pair of anticyclones, and the strong westerly gales are but part of the circulation about these high pressures. (See Charts 29 and 30.)

The one selected for illustration occupied the whole of Australia on June 4th, 1895, Chart 36. Its form was remarkably symmetrical, and in the central area the barometers read 30·6, which is somewhat unusual, hence the circulation is active, and in northern Australia where the trade wind adds force, it is very strong. Under the central influence of these great anticyclones the whole of Australia enjoys fine weather.



TYPE XIX.—SQUARE HEADED Λ DEPRESSION.

This type is a variation of the usual Λ depression, but is sufficiently characteristic to be placed by itself as a type or rather a sub-type. Its isobaric peculiarity, as may be seen by reference to Charts 37 and 38, is that there is a flat top or square head to the isobars of the Λ, the usual form of which is a sharp and regular curve, and the marked feature of this is that under it the weather is remarkably squally and charged with thunder

and hail storms, and deluges of rain. This type is not peculiar to any season of the year, and the country they affect is usually south of Lat. 30°. The particular square headed ∧ depression under discussion occurred in July, 1891. Its effects were widespread and its life persistent, and its peculiarity in a more or less distinctive form was maintained during its passage over six degrees of longitude, and its effects most severe in Victoria.

In Chart 37, July 8th, 1891, the square headed ∧ is shown when over South Australia. The gradients about it excepting those on its eastern side were moderate; winds were from fresh to strong. Following it is a high pressure of decided energy, and preceding it to the east an anticyclone of little or no character on the previous day rain fell over greater part of the southern seaboard and in Tasmania.

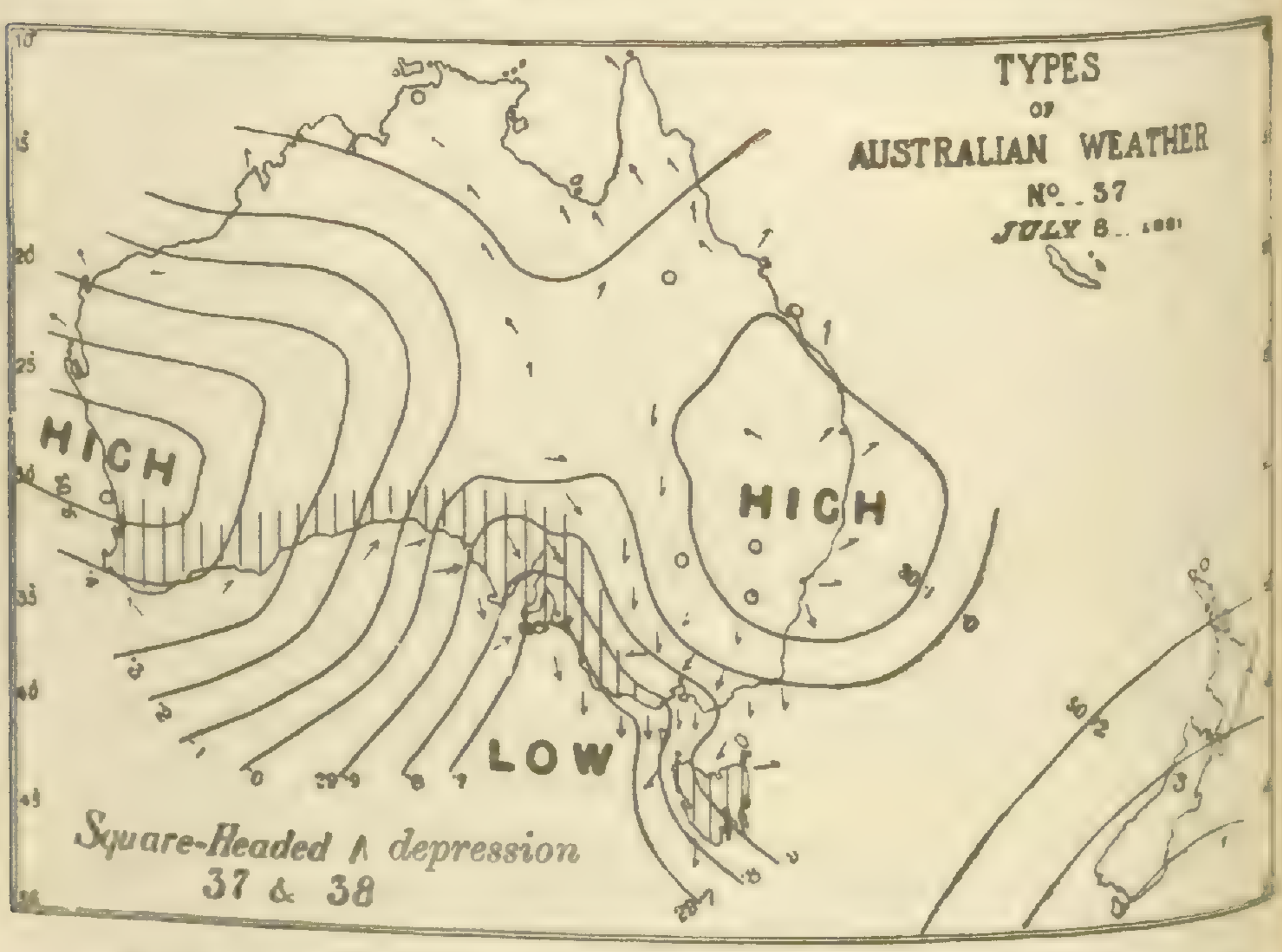
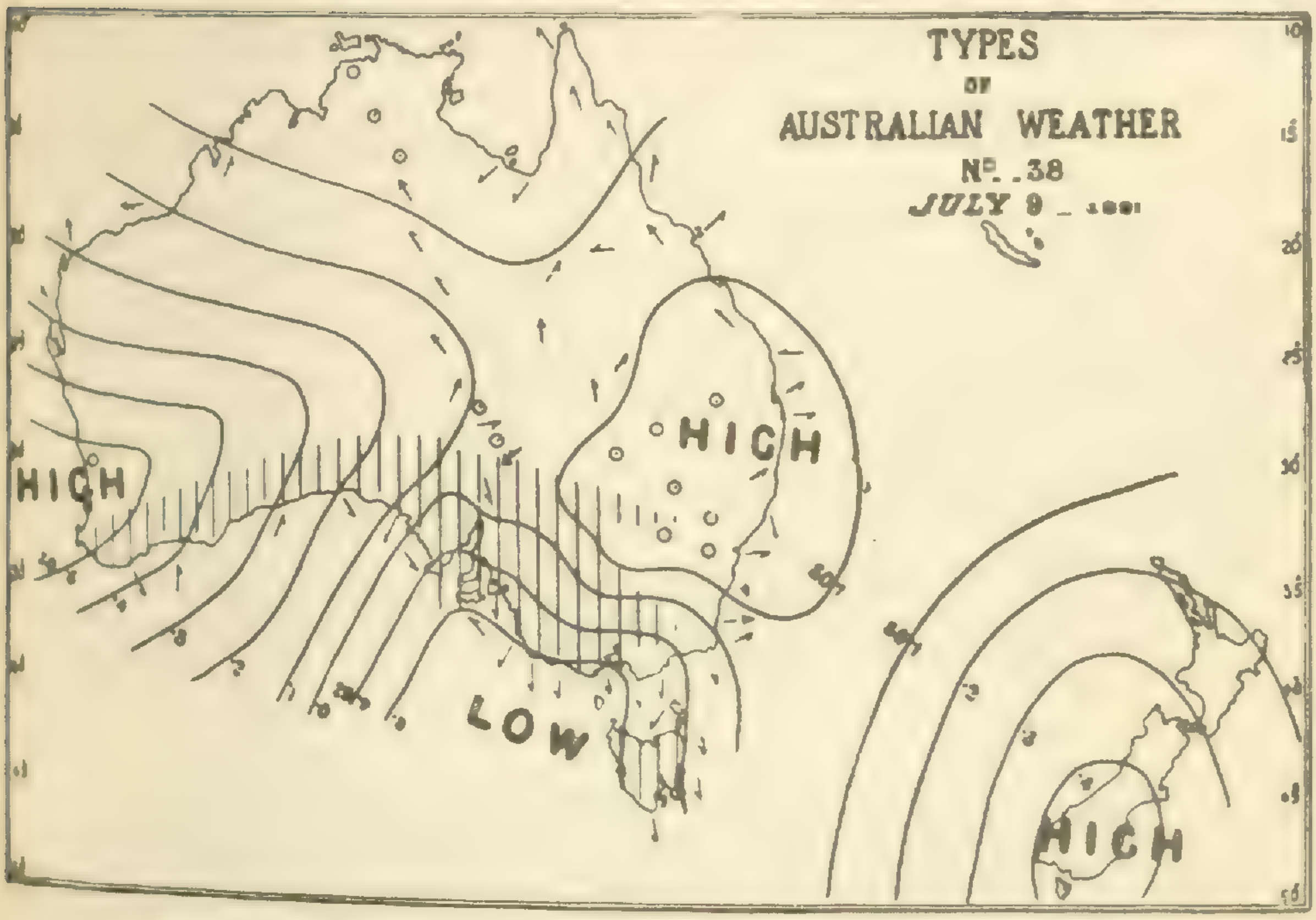


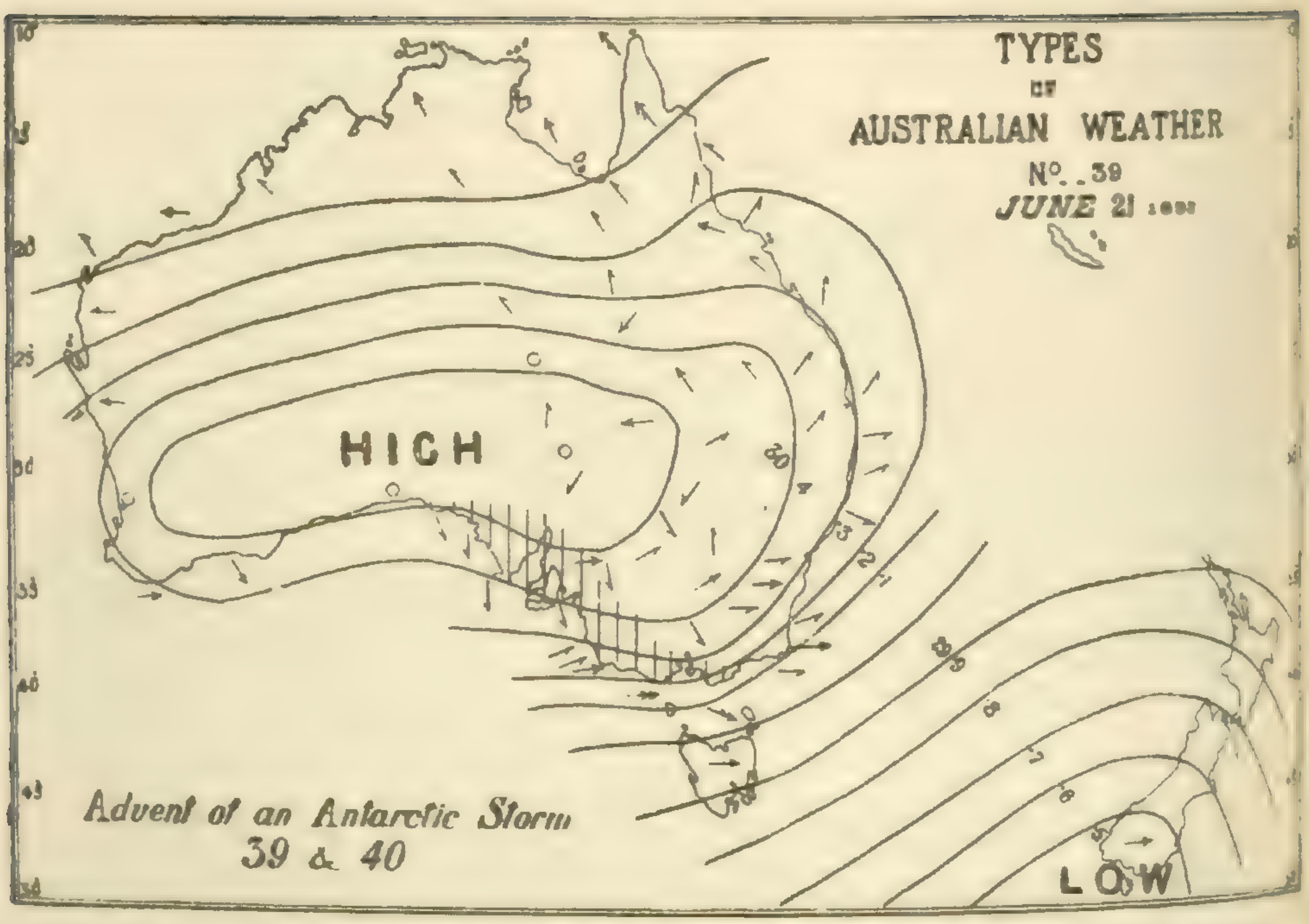
Chart 38, July 9th, the depression has become more extensive but has lost energy. The relative powers of the anticyclones remains the same, winds were generally lighter, but the rain covered a much wider area than on the previous day. As the storm moved to the east its characteristic weather was maintained



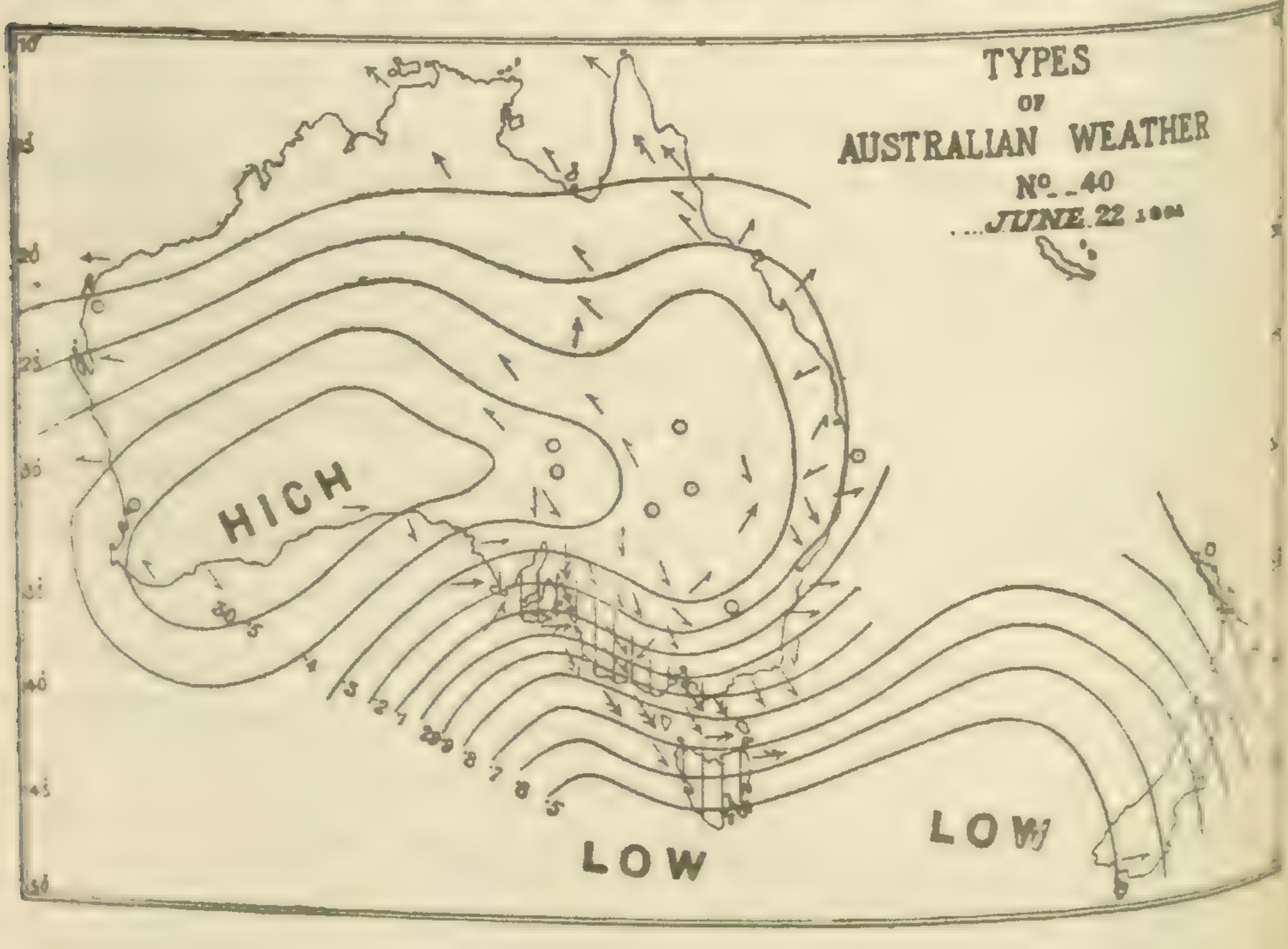
TYPE XX.—THE ADVENT OF AN ANTARCTIC STORM.

This is a type of weather that does not often visit Australia but its severity makes it noteworthy for the winds and weather which come with it are very destructive, and the cold severe, it might almost be called a southern blizzard; yet the warning is short and often difficult to read, for it comes from the Antarctic where we have no out stations.

The storm under consideration began to affect the south coast of Australia, making the winds fresh to strong on June 21st, 1892, (Chart 39), yet the season (winter) and the general conditions pointed to westerly winds, and said nothing definite of the storm which was telegraphed on the morning of June 22nd, (Chart 40). Barometers were then seen to be four-tenths lower in Tasmania than they were on the 21st, and the wind had increased to a furious gale along the south coast of South Australia and Victoria, and the isobars indicate a very steep grade commensurate with the wind. On shore also the wind rose in places to hurricane force: at Ballarat, in western Victoria, buildings were unroofed and trees blown down. So severe was it there that the storm is recorded as the Ballarat storm.



In South Australia and New South Wales the wind did a great deal of damage without reaching the intensity it had in Victoria. The isobars show a retreat of the anticyclone and a tilting of the major axis, and a very remarkable increase in the number of isobars on the south coasts of South Australia, Victoria, and



Tasmania. It looks as if the low pressure had retreated and its western parts forced their way north. What probably did take place was that a storm centre south of the Australian Bight and indicated by the northerly winds in Chart 39, had in the interval surged northwards on to the west coast of Victoria, bringing with it all its antarctic energy and severe cold. This view is supported by the fact that there was in the twenty-four hours but little change in the New Zealand isobars, and further by the upward tilting of the eastern part of the anticyclone caused by the northing of the antarctic storm, and lastly by the blizzard-like cold which was so marked a feature of this storm.

LIST OF TYPES OF AUSTRALIAN WEATHER.

I.—Moving Anticyclones, Charts 1, 2, 3.
II.—Monsoonal Rain Storm, Charts 4, 5.
III.—Development of a Cyclonic Storm in Low Latitudes from a Monsoonal Depression, Charts 6, 7.
IV.—Development of a Cyclonic Storm in High Latitudes from a Monsoonal Depression, Charts 8, 9, 10.
V.—Conditions favourable for Thunderstorms, Charts 11, 12.
VI.—Cyclonic Thunderstorms, Charts 13, 14.
VII.—Vertical and nearly straight Isobars, Charts 15, 16.
VIII.—Cyclones from North-West, Charts 17, 18, 19.
IX.—Cyclones from North-East, Charts 20, 21, 22.
X.—Tornadoes, Charts 23, 24.
XI.—South-East Gales, Charts 25, 26.
XII.—Development of Cyclones from a ∧ Depression, Charts 27, 28.
XIII.—Westerly Winds, Charts 29, 30.
XIV.—Southerly Bursters, Charts 31, 32.
XV.—Black North-Easter, Chart 33.
XVI.—Winds Blowing Against Isobars, Chart 34.
XVII.—Summer Anticyclone, Chart 35.
XVIII.—Winter Anticyclone, Chart 36.
XIX.—Square Headed ∧ Depression, Charts 37, 38.
XX.—Advent of an Antarctic Storm, Charts 39, 40.

PROCEEDINGS

OF THE

ROYAL SOCIETY OF NEW SOUTH WALES.

WEDNESDAY, MAY 1, 1895.

Annual General Meeting.

Prof. R. Threlfall, M.A., President, in the Chair.

Fifty-three members and nine visitors were present.

The minutes of the preceding meeting were read and confirmed.

The following Financial Statement for the year ending 31st March, 1895, was presented by the Hon. Treasurer, and adopted:—

GENERAL ACCOUNT.

Receipts.	£	s.	d.	£	s.	d.
Subscriptions: One Guinea	155	8	0			
Subscriptions: Two Guineas	441	0	0			
Subscriptions: Arrears	49	7	0			
Subscriptions: Advances	3	3	0	648	18	0
Entrance Fees and Compositions				56	14	0
Parliamentary Grant on Subscriptions received during 1894				500	0	0
Rent of Hall				22	4	6
Sundries				6	13	6
Total Receipts				1234	10	0
Balance on 1st April, 1894				63	12	3
				£1298	2	3

Payments.	£	s.	d.	£	s.	d.
Advertisements	27	16	6			
Assistant Secretary	250	0	0			
Books and Periodicals	100	13	10			
Bookbinding	61	16	0			
Conversazione	69	13	1			
Freight, Charges, Packing, &c....	9	4	7			
Furniture and Effects	4	10	0			
Carried forward	£523	14	0			

PAYMENTS—*continued.*	£	s.	d.	£	s.	d.
Brought forward	523	14	0			
Gas	27	17	2			
Housekeeper	10	0	0			
Insurance	10	14	0			
Office Boy	20	16	0			
Petty Cash Expenses	15	19	0			
Postage and Duty Stamps	32	15	0			
Printing	36	10	0			
Printing and Publishing Journal	301	2	0			
Prize Essay Awards	50	0	0			
Rates	48	14	2			
Refreshments and attendance at Meetings ...	21	0	6			
Repairs	22	5	9			
Stationery	7	2	5			
Sundries	12	7	4			
Total Payments				1140	17	4
Transfer to Building and Investment Fund...				106	14	0
Balance on 31st March, 1895				50	10	11
				£1298	2	3

BUILDING AND INVESTMENT FUND.

RECEIPTS.	£	s.	d.
Transfer from General Account	106	14	0
Interest on Fixed Deposit	50	15	8
Amount of Fund on 1st April, 1894	1128	10	5
	£1286	0	1

	£	s.	d.
Fixed Deposit in Union Bank	1286	0	1
	£1286	0	1

CLARKE MEMORIAL FUND.

RECEIPTS.	£	s.	d.
Interest on Fixed Deposit	15	9	7
Amount of Fund on 1st April, 1894	344	1	5
	£359	11	0

	£	s.	d.
Fixed Deposit in Government Savings Bank	179	15	6
Fixed Deposit in Savings Bank of New South Wales ...	179	15	6
	£359	11	0

ABERCROMBY FUND.

RECEIPTS.

	£	s.	d.
Amount received from the Hon. Ralph Abercromby to be offered as Prizes for Competitive Essays on various phases of Australian weather	100	0	0
Interest on Fixed Deposit, 1893	4	10	0
Interest on Fixed Deposit, 1894	4	13	7
	£109	3	7

	£	s.	d.
Award for Prize Essay on "Southerly Bursters"	25	0	0
Illustrations for Ditto	16	3	9
Fixed Deposit in Union Bank	67	19	10
	£109	3	7

AUDITED, P. N. TREBECK.
H. O. WALKER.

SYDNEY, 19th April, 1895.

H. G. A. WRIGHT, *Honorary Treasurer.*
W. H. WEBB, *Assistant Secretary.*

Messrs. Henry Deane and Josiah Mullens were appointed Scrutineers for the election of officers and members of Council.

A ballot was then taken and the following gentlemen were duly elected officers and members of Council for the current year:

Honorary President:

Prof. T. W. E. DAVID, B.A., F.G.S.

Vice-Presidents:

F. B. KYNGDON.
CHARLES MOORE, F.L.S., F.Z.S.
PROF. T. P. ANDERSON STUART, M.D.
PROF. THRELFALL, M.A.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, L.S.A. *Lond.*, &c.

Hon. Secretaries:

J. H. MAIDEN, F.L.S.
J. W. GRIMSHAW, M. INST. C.E.

Members of Council:

W. CHISHOLM, M.D.
C. W. DARLEY, M. INST. C.E.
HENRY DEANE, M.A., M. INST. C.E.
W. M. HAMLET, F.C.S., F.I.C.
G. H. KNIBBS.
H. A. LENEHAN, F.R.A.S.
PROF. LIVERSIDGE, M.A., F.R.S.
E. F. PITTMAN, ASSOC. R.S.M., B.A.
H. C. RUSSELL, B.A., C.M.G., F.R.S.
ALFRED SHEWEN, M.D.

The following gentlemen were duly elected ordinary members of the Society:

Adams, John Henry; Orange.

Bancroft, Thomas L., M.B. *Edin.;* Brisbane.

The certificates of two candidates were read for the second time, and of five for the first time.

The names of the Committee-men of the different Sections were announced :—

Section H.—Medical.

Chairman—Dr. W. H. Goode, M.A.

Secretaries—Dr. G. E. Rennie, B.A. and Dr. C. J. Martin, B.Sc.

Committee—Dr. P. Sydney Jones, Dr. Cecil Purser, Dr. Alfred Shewen, Hon. Dr. H. N. MacLaurin, M.L.C., M.A.

Three Meetings were held, viz.—June 21st, August 16th, and October 18th, at 8·15 p.m.

Section K.—Engineering.

Chairman—B. C. Simpson, M. Inst. C.E.

Secretary—T. H. Houghton, Assoc. M. Inst. C.E.

Treasurer—J. W. Grimshaw, M. Inst. C.E.

Committee—C. O. Burge, M. Inst. C.E., Joseph Davis, M. Inst. C.E., Thomas Rhodes Firth, M. Inst. C.E., W. F. How, M. Inst. C.E., Wh. Sc., D. M. Maitland, L.S., J. M. Smail, M. Inst. C.E.

Past Chairmen, *ex officio* Members of Committee for three years: Cecil W. Darley, M. Inst. C.E., H. Deane, M.A., M. Inst, C.E., and R. R. P. Hickson, M. Inst. C.E.

Meetings held on the Third Wednesday in each month, at 8 p.m.

The President called attention to the footnote on the Prize Essay circulars, to the effect that papers submitted would be received only on the condition that, if awarded a prize, they would become amenable to Rule XXVIA. of the Society.

He also announced that the Clarke Memorial Medal for 1895 had been awarded to Mr. Robert Logan Jack, F.G.S., &c., Government Geologist of Queensland, and to Mr. Robert Etheridge, Junr., Government Palæontologist, Department of Mines, Sydney.

The medal was then presented to Mr. Etheridge, who expressed his appreciation of the honour conferred upon him.

The following letters were received acknowledging the award :

Geological Survey of Queensland,
George-street, Brisbane,
3rd December, 1894.

The Hon. Secretaries, Royal Society of N.S. Wales, Sydney.

Gentlemen—Your announcement, (dated 14th ult.), that the Council of the Royal Society of New South Wales had awarded me the Clarke Memorial Medal, awaited me on my return from a journey in the interior, and added to my welcome home a satisfaction for which I was entirely unprepared.

This mark of appreciation of my part in the study of the geological history of Australia is peculiarly grateful to my feelings, both on account of the authority from which it emanates and of the connection of my name with that of the revered geologist in whose memory the distinction was founded; and, permit me to say that if anything could heighten the pleasure with which I receive the announcement, it is the fact that my colleague and friend Mr. Robert Etheridge Junior, is to share the honour conferred by the Society.

In conveying my sincere thanks to the Council, be good enough to assure them that the medal will be prized not merely as a recognition of past service, but as an encouragement to renewed effort during the remainder of my career.

I am gentlemen, yours very truly,
ROBERT L. JACK.

"Alladale," Old Canterbury Road, Petersham,
Sydney, 16th November, 1894.

Dear Mr. Maiden,—I beg to acknowledge your letter of November 14, informing me that the Council of the Royal Society had been pleased to award me a "Clarke Memorial Medal."

Will you be kind enough to convey to the Council my most sincere thanks for the honour conferred, the more pleasing to me, as it was quite unexpected. You may assure the Council that this recognition of my humble efforts towards the elucidation of a most fascinating study—Australian Palæontology—will still further tend towards enlivening my future investigations in that direction.

I am very faithfully yours,
R. ETHERIDGE.

To J. H. Maiden, Esq., Hon. Secretary, Royal Society, N. S. Wales.

Eighty-seven volumes, four hundred and twenty-seven parts, twenty-nine reports, twenty-three pamphlets, and seven hydrographic charts received as donations since the last meeting were laid upon the table and acknowledged.

Prof. THRELFALL, M.A., then read his address.

A vote of thanks was passed to the retiring President, and Prof. T. W. E. DAVID, B.A., F.G.S., was installed as President for the ensuing year.

Prof. DAVID thanked the members for the honour conferred upon him.

WEDNESDAY, JUNE 5, 1895.

CHARLES MOORE, F.L.S., Vice President, in the Chair.

Thirty members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two new candidates were read for the third time, of five for the second time, and of two for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Boultbee, J. W., Superintendent of Public Watering Places.

Frackelton, Rev. W. S., M.Sc., B.D.; Randwick.

Fifty-four volumes, three hundred and seventy-eight parts, sixteen reports, ninety-nine pamphlets, and two hydrographic charts received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "Aeronautical Work," by LAWRENCE HARGRAVE.
2. "A contribution to the chemistry of Myrtaceous Kinos," by J. H. MAIDEN, F.L.S., &c., and HENRY G. SMITH.
3. "Note on two alteration products derived from the mineral Dyscrasite and argentiferous Galena, found in the Broken Hill Consols Mine," by E. F. PITTMAN, A.R.S.M.
4. "The cubic parabola as applied to the easing of circular curves on Railway Lines," by C. J. MERFIELD, (Communicated by G. H. KNIBBS, L.S.)

EXHIBITS :

Mr. PITTMAN exhibited specimens of the two mineral substances showing in places the action of the two solvents referred to in his

paper, namely :—"Alteration product after Dyscrasite, composition chiefly chloride of silver and antimoniate of silver." A small area of the polished surface has been etched by means of strong ammonia. The chloride of silver has thus been removed, leaving the antimoniate of silver in relief. "Alteration product after argentiferous Galena, composition chiefly sulphate of lead and sulphide of silver, in variable proportions." One side of the small polished piece has been etched by means of a solution of acetate of ammonia. The sulphate of lead has thus been removed leaving the sulphide of silver in relief. He also exhibited a specimen from the White Cliffs near Wilcannia. It consisted of a water-worn boulder of Devonian sandstone (containing typical Devonian fossils), found in the Upper Cretaceous rocks at the opal mines. One half of the boulder had been subjected to the action of thermal silicious waters, with the result that that part of the stone had been completely vitrified, and the fossils had been converted into precious opal.

WEDNESDAY, JULY 1, 1895.

Prof. T. W. E. DAVID, B.A., F.G.S., President, in the Chair.

Thirty members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of five new candidates were read for the third time, and of three for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Barraclough, S. H., B.E., M.M.E. ; Glebe Point.
Bensusan, A. J., A.R.S.M., F.C.S. ; Burwood.
Jacob, A. F., A.M.I.C.E.; Dulwich Hill.
Nicholls, W. H. ; Gosford.
Van de Velde, Clement, C.E.; Sydney.

The President made the following announcements :—

1. The death of the Rt. Hon. Prof. Huxley, F.R.S., P.C., who was elected an Honorary Member of the Society in 1879, and was awarded the Clarke Medal in 1880.

2. That the Council recommend the election of the following gentlemen as Honorary Members of the Society, viz.:—

Prof. Robert Wilhelm Bunsen, For. Mem. R.S.; Heidelberg.

Dr. Alfred Russel Wallace, F.R.S., Parkstone, Dorset.

The election was carried unanimously.

3. That a course of two or three Lectures in connection with the Clarke Memorial would probably be given by Prof. T. W. E. David, B.A., F.G.S., and Mr. E. F. Pittman, A.R.S.M., Government Geologist, in September or November next.

4. That the Society's Bronze Medal and Prize of £25 had been awarded to Charles James Martin, B.Sc. M.B. *Lond.*, M.R.C.S. *Eng.*, for paper upon "The physiological action of the venom of the Australian black snake, *Pseudechis porphyriacus*."

The medal and cheque were then presented to Dr. Martin.

Nine volumes, one hundred and sixty-one parts, six reports, four pamphlets, and one hydrographic chart, received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "On the great Meteor of May 7th," by H. C. Russell, B.A., C.M.G., F.R.S.

Some remarks were made by Dr. Martin, Prof. David, and the Author.

2. "The history, theory, and determination of the viscosity of water by the efflux method," by G. H. Knibbs, L.S.

Some remarks were made by Mr. J. A. Pollock and the Author.

3. "On the physiological action of the venom of the Australian black snake *Pseudechis porphyriacus*," by Dr. C. J. Martin, B.Sc.

Some remarks were made by the Chairman.

WEDNESDAY, AUGUST 7, 1895.

Prof. T. W. E. David, B.A., F.G.S., President, in the Chair.

Twenty-eight members were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of three candidates were read for the second time.

Seventy-three volumes, one hundred and eighty-two parts, eight reports and ten pamphlets received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "Some Folk-songs and Myths from Samoa," by Dr. JOHN FRASER, B.A.

   Some remarks were made by the Rev. Dr. W. Wyatt Gill and the Chairman.

2. "Rocks of Victoria Land and Possession Island," collected by Mr. C. E. Borchgrevink, with "Notes on the Geology of Antarctica," by Prof. T. W. E. DAVID, B.A., F.G.S., and W. F. SMEETH. M.A., A.R.S.M.

3. "Considerations on the surviving refugees, in Austral Lands, of ancient Antarctic life," by C. HEDLEY, F.L.S.

The discussion on the above papers was postponed to the next meeting.

EXHIBITS :

1. Photographs showing the crystalline structure of gold ingots, by Prof. LIVERSIDGE, M.A., F.R.S.

2. Exhibits to accompany the papers by Prof. DAVID and Mr. W. F. SMEETH.

3. Photographs of scenes of geological interest in N. S. Wales, taken and prepared for the stereoscope by His Honour Judge DOCKER, M.A.

4. Comic portrait of himself in pen and ink by Prof. Huxley, also water-colour painting of an island in the Torres Straits by the same.—Exhibited by Mr. C. HEDLEY.

WEDNESDAY, SEPTEMBER 4, 1895.

Prof. T. W. E. DAVID, B.A., F.G.S., President, in the Chair.

Thirty-one members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of three new candidates were read for the third time.

The following gentlemen were duly elected ordinary members of the Society :—

Ross, Colin John, B.Sc., B.E., A.M.I.C.E.; Sydney.
Ross, Herbert E. ; Sydney.
Ward, James Wenman ; Sydney.

The Chairman made the following announcements, viz :—

1. That the Society would shortly be connected with the Telephone Exchange.

2. That members using the Library could, if they wished, be supplied with a cup of tea, &c., price 6d.

3. That the Society had purchased fourteen feet of land adjoining their present premises.

Five volumes, sixty-three parts, three reports, four pamphlets, and eighteen hydrographic charts, received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "Contributions to a knowledge of Australian vegetable exudations, No. 1," by J. H. MAIDEN, F.L.S. &c., and H. G. SMITH.

Some questions were asked by the President, to which Mr. Maiden replied.

2. "Icebergs in the Southern Ocean," by H. C. RUSSELL, B.A., C.M.G., F.R.S.

A discussion followed in which the Hon. Dr. Creed, Mr. W. F. Gale, Mr. P. N. Trebeck, and the President took part.

Mr. WALTER F. GALE, F.R.A.S., said he had listened with considerable pleasure to Mr. Russell's paper. There could be no doubt as to the great value of a more complete knowledge of the extent and movements of the ice encountered by vessels proceed-

ing both to and from Australia. He perceived that Mr. Russell made no reference to black or discoloured ice, such as was recorded in large quantities in 1892 and 1893. The barque by which he had travelled encountered twenty-three ice-masses of this character. The majority were of small extent, and resembled whales' backs, but several were true bergs. One measured upwards of three miles in length, with a maximum height out of water of about eighty feet. The colour was dark brown or black, and it had occurred to him that this colouring might throw some light upon the genesis of the icebergs usually met with in running down the easting. Whatever theory might be advanced to account for the colouration of the smaller masses, there was little doubt in his mind that the true bergs appeared black from the presence of matter ejected during the long continued action of an antarctic volcano. The observation of an uncommon berg, such as the one referred to, by officers of vessels in different latitudes, would certainly be of more than ordinary value in connection with the rates of drift and melting, since the identification would be more easy than usual. He regretted to think that even the extensive records Mr. Russell had had the good fortune to receive could hardly be regarded as sufficient for definite conclusions relating to this important subject; owing to the lack of approximately simultaneous observations in different latitudes. This was exemplified in his own experience during a recent voyage to Chili. His vessel's track lay between 50° and 51° south latitude, and no ice was seen in March. Bergs were reported, however, during the same month by a vessel whose track lay 3° to the northward. Either report alone might have led to an incorrect conclusion, so it was to be hoped that shipmasters would report negative experience, in order that the author might form as complete a theory as possible.

The discussion upon the papers by Prof. T. W. E. David, B.A., F.G.S., and W. F. Smeeth, M.A., A.R.S.M., and by C. Hedley, F.L.S., read at the previous meeting were further postponed to the October meeting.

WEDNESDAY, OCTOBER 2, 1895.

Prof. T. W. E. DAVID, B.A., F.G.S., President, in the Chair.

Forty-one members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

Forty volumes, one hundred and six parts, fifteen reports, sixteen pamphlets and one hydrographic chart, received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "On the amount of gold and silver in sea-water," by Prof. LIVERSIDGE, M.A., F.R.S.

2. "The removal of silver and gold from sea-water by Muntz metal sheathing," by Prof. LIVERSIDGE, M.A., F.R.S.

Some remarks were made by the President.

3. "Notes on equable temperatures, Lord Howe Island," by H. C. RUSSELL, B.A., C.M.G., F.R.S.

Some remarks were made by Mr. Carment, to which Mr. Russell replied.

Mr. C. HEDLEY gave an outline of the paper read by him on the 7th August, viz.:—"Considerations on the surviving refugees in Austral lands of ancient Antarctic life."

The subject was discussed at some length by the President.

Mr. RUSSELL exhibited (and afterwards presented to the Society) a photograph of a flash of lightning two miles long, taken at the Sydney Observatory on the 16th September.

WEDNESDAY, NOVEMBER 6, 1895.

Prof. T. W. E. DAVID, B.A., F.G.S., President, in the Chair.

Forty-two members and nine visitors were present.

The minutes of the preceding meeting were read and confirmed.

Twelve volumes, one hundred and fourteen parts, nine reports, five pamphlets, two hydrographic charts and one astronomic-

chart, received as donations since the last meeting were laid on the table and acknowledged.

A letter was received from Prof. R. W. BUNSEN, For. Mem. R.S., Heidelberg, acknowledging his election as an Honorary member.

The President read a circular stating that steps were being taken in London, to found a National Memorial to the late Right Hon. T. H. Huxley, and announced that if any of the members or general public were desirous of contributing to this object, the Hon. Treasurer (Dr. Wright), would be happy to receive and transmit their subscriptions.

The following papers were read :—

1. "On some New South Wales and other Minerals, (Note No. 7)" by Prof. LIVERSIDGE, M.A., F.R.S., &c.

2. "On a natural deposit of Aluminium succinate in the timber of *Grevillea robusta*," by J. H. MAIDEN, F.L.S. &c., and H. G. SMITH.

Some remarks were made by Mr. Hamlet, Prof. Liversidge, the President and Mr. Maiden.

3 "The extinct volcanoes of the Warrumbungle Mountains," by His Honor Judge DOCKER, M.A., and Prof. T. W. E. DAVID, B.A., F.G.S. Lantern views were shown, described, and formed the basis of interesting observations on the geology of the district.

4. "Geological Laboratory Notes, (Note No. 1)," by the Rev. J. MILNE CURRAN.

Some remarks were made by the President.

EXHIBITS :

The oil of *Pittosporum undulatum* by Prof. THRELFALL.

Selenium bearing stone, trachyte, &c. by Rev. J. M. CURRAN.

WEDNESDAY, DECEMBER 4, 1895.

Prof. T. W. E. DAVID, B.A., F.G.S., President, in the Chair.

Forty-nine members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificate of one new candidate was read for the first time.

Thirty-seven volumes, one hundred and fifteen parts, eleven reports, forty-five pamphlets, nineteen meteorological charts and four hydrographic charts, received as donations since the last meeting were laid upon the table and acknowledged.

Mr. MAIDEN gave notice that at the next Annual General Meeting, he intended to move that the whole of the last paragraph of Rule XIV. be omitted, viz.:—"At the meeting held in July, and at all subsequent meetings for the year, a list of the names of all those members who are in arrears with their annual subscriptions shall be suspended in the Rooms of the Society. Members shall in such cases be informed that their names have been thus posted."

It was resolved that Messrs. P. N. TREBECK and J. W. MCCUTCHEON be appointed Auditors for the current year.

The following papers were read :—

1. "On the assimilation of gold by fungoid growths," by Prof. LIVERSIDGE, M.A., F.R.S.

   Some remarks were made by Messrs. J. W. McCutcheon, W. D. Campbell, and the President.

2. "The origin of malachite ; observations made in an abandoned copper mine" by EDGAR HALL, this paper was communicated and read by Prof. LIVERSIDGE.

   Some remarks were made by Messrs. W. M. Hamlet, W. D. Campbell, and Prof. Liversidge.

3. "Notes on the geology of Antarctica (Part 2)" by Prof. T. W. E. DAVID, B.A., F.G.S., W. F. SMEETH, M.A., A.R.S.M., and J. A. SCHOFIELD, F.C.S., A.R.S.M.

   This paper was read by Mr. Smeeth, and some remarks were made by the President.

4. "On the occurrence of Artesian water in rocks other than the Cretaceous," by E. F. PITTMAN, A.R.S.M.

Some remarks were made by the President.

5. "The tensile and compressive strengths of Magnesium," by S. H. BARRACLOUGH, B.E., M.M.E.

Some remarks were made by Prof. Threlfall and the President.

6. "On the products from the fruit of *Pittosporum undulatum* and *Schinus molle*," by Prof. THRELFALL, M.A.

7. "Types of Australian Weather," by H. A. HUNT. This paper was prepared as an essay under the Abercromby Prize Fund and was read by Mr. H. C. RUSSELL.

8. "Rainfall of Southern Riverina 1874 – 94," by H. C. KIDDLE, F.R. Met. Soc. This paper was also read by Mr. RUSSELL.

PROCEEDINGS OF THE SECTIONS.

(IN ABSTRACT.)

ENGINEERING SECTION.

At the preliminary meeting held on April 17th, the following officers were elected for the 1895 Session :—Chairman : Mr. B. C. SIMPSON, M. Inst. C.E. Hon. Secretary : Mr. T. H. HOUGHTON, Assoc. M. Inst. C.E., M. Inst. Mech. E. Hon. Treasurer : Mr. J. W. GRIMSHAW, M. Inst. C.E., M. Inst. Mech. E. Committee : Messrs. D. M. MAITLAND, L.S., C. O. BURGE, M. Inst. C.E., W. F. HOW, M. Inst. C.E., Wh. Sc., J. M. SMAIL, M. Inst. C.E., T. R. FIRTH, M. Inst. C.E., and J. DAVIS, M. Inst. C.E.

The *ex officio* members of the Committee being Messrs. C. W. DARLEY, M. Inst. C.E., H. DEANE, M.A., M. Inst. C.E., R. R. P. HICKSON, M. Inst. C.E.

Messrs. HAYCROFT and SMITH the Auditors appointed by the meeting, reported that there was a balance of £16 8s. 7d. in the hands of the Hon. Treasurer to the credit of the printing fund.

Monthly meeting held May 15, 1895.

Mr. B. C. SIMPSON, in the Chair.

Thirty-five members and visitors present.

The Chairman delivered an inaugural address.

Mr. H. DEANE then read a paper on "Some recent Engineering Developments in England and America."

Monthly meeting held June 19, 1895.

Mr. B. C. SIMPSON in the Chair.

Twenty-seven members and visitors present.

Messrs. Cowdery, Selfe, Grimshaw, and Simpson asked Mr. Deane for information in connection with his paper "Some recent Engineering Developments in England and America," which the author supplied.

The discussion on Mr. W. S. de LISLE ROBERTS' paper "Recent Researches in the Testing of Cement," and Mr. W. M. HAMLET'S paper "The interpretation of Cement Analyses" was opened by Mr. J. Davis and continued by Messrs. Richards, Haycroft, Deane, and Grimshaw, and adjourned to the next meeting.

Monthly meeting held July 17, 1895.

Mr. B. C. SIMPSON, in the Chair.

Twenty-eight members and visitors present.

Mr. C. O. BURGE read a paper on "The Preparation of Engineering Specifications and General Conditions for large Works," the discussion was postponed until the next meeting.

The discussion on Messrs. ROBERTS' and HAMLET'S papers on Cement Testing was resumed by Dr. McDonagh, and continued by Messrs. Henson, Mingaye, Davis, Try, Farr, Dixon, Allan, Simpson, and Hamlet.

Monthly meeting held August 21, 1895.

Mr. B. C. SIMPSON, in the Chair.

Twenty-three members and visitors present.

Mr. W. S. de LISLE ROBERTS replied to the discussion of his paper on "Recent Researches in the Testing of Cement."

The discussion of Mr. C. O. BURGE's paper "The Preparation of Engineering Specifications and General Conditions for large Works," was opened by Mr. How, and continued by Messrs. Grimshaw, Farr, Shaw, and Allan, and adjourned to the next meeting.

Monthly meeting held September 18, 1895.

Mr. H. DEANE, in the Chair.

Twenty-nine members and visitors present.

Mr. P. ALLAN read a paper on "Timber Bridges," the discussion was postponed to a future meeting.

The discussion of Mr. C. O. BURGE's paper "The Preparation of Engineering Specifications and General Conditions for large Works," was resumed by Mr. Smail, and continued by Messrs. Mansfield, Rowe, Haycroft, Selfe, Barraclough, and Deane, and replied to by the author.

Monthly meeting held October 16, 1895.

Mr. B. C. SIMPSON, in the Chair.

Twenty-three members and visitors present.

A paper communicated by Mr. T. E. BURROWS entitled "Fascine Work as carried out by the Public Works Department in New South Wales," was read by Mr. Grimshaw, and the discussion postponed to a future meeting.

Mr. J. M. SMAIL read a paper entitled "Notes on the under-draining of the Filter Beds at the Botany Sewage Farm."

Monthly meeting held November 20, 1895.

Mr. B. C. SIMPSON, in the Chair.

The discussion of Mr. P. ALLAN's paper "Timber Bridges" was opened by Mr. Deane and continued by Messrs. Burge, Smail, Barraclough, Statham, and Simpson, and replied to by the author.

Monthly meeting held December 18, 1895.

Mr. B. C. SIMPSON, in the Chair.

Twenty-two members and visitors were present.

The discussion of Mr. BURROW's paper "Fascine Work as carried out by the Public Works Department in New South Wales," was opened by Mr. Darley, and continued by Messrs. Smail, Deane, Grimshaw, Allan, and Simpson, and replied to by the author.

During the Session the Section visited, by invitation, the Ocean Street Cable Tram Power House, Messrs. Anthony Hordern's Hydraulic and Electric Light Plant, the Botany Sewage Farm, and the Rosehill and Dural Railway.

Subscriptions to the printing fund have been received amounting to £21 0s. 6d., and £5 by sale of papers.

MEDICAL SECTION.

At the provisional meeting of the Medical Section held on April 19th, 1895, the following officers were elected :—Chairman: Dr. W. H. GOODE, M.A. Committee: Hon. Dr. MACLAURIN, M.LC., Drs. SYDNEY JONES, SHEWEN, and PURSER. Secretaries: Drs. G. E. RENNIE and C. J. MARTIN.

It was decided to hold only three meetings during the year.

The Committee were instructed to revise the Rules of the Section.

SPECIAL GENERAL MEETING.

A Special General meeting was held on June 21st, at 8 p.m., at which the draft of the rules as revised by the Committee was agreed to, and ordered to be forwarded to the Council for their approval.

First General Meeting.

The first general meeting was held on June 21st, at 8·15 p.m. Dr. W. H. Goode, M.A., in the Chair.

Dr. MacDonald Gill, exhibited a case of sporadic cretinism and also one of myxoedema.

Dr. Rennie exhibited two cases of myxoedema which had been under treatment with thyroid tabloids.

The Hon. Secretary exhibited for Dr. Scot Skirving, two cases of Friedreich's disease. These patients were examined by the members and afterwards discussed.

Dr. Milford read some notes on the treatment of diphtheria with Resorcin.

The paper was discussed by Drs. Megginson, Crago, Neill, Sydney Jones, and McDonagh. The remaining business was postponed.

Second General Meeting.

The second general meeting was held August 16th. Dr. W. H. Goode in the Chair.

Dr. J. A. Dick read some notes on a case of Malignant Disease of the Lung and exhibited the specimen, and also some microscopical sections of the growth.

Dr. Rennie read a paper on "Death after Head Injuries," which was criticised by Prof. Anderson Stuart, Drs. McDonagh, Chisholm, and Angel Money.

Dr. R. L. Faithfull read a paper on "Significance of Albuminuria more especially as regarded by medical examiners for Life Insurance." Remarks were made on the subject by Drs. Sydney Jones, Angel Money, and Rennie.

Dr. C. J. Martin exhibited a simple and efficient method of drying serum and maintaining it sterile during the process.

The Secretaries were instructed to write a letter expressing the sympathy of the members of the Section with Mrs. L. R. Huxtable on the death of her husband.

Third General Meeting.

The third and last meeting of the year was held on Oct. 15th, at 8·15 p.m. Dr. W. H. Goode, M.A., in the Chair.

Dr. Macdonald Gill exhibited a case of sporadic cretinism, and also one of Raynard's disease.

Dr. Jamieson exhibited an infant suffering from congenital syphilis and tumour in the sterno-mastoid.

Prof. Anderson Stuart gave a demonstration of his new form of artificial larynx, and exhibited the patient with the larynx *in situ*.

Dr. Milford exhibited two cases of old injury to the skull.

Dr. Jamieson read a paper on some cases illustrating the effects of syphilis on the central nervous system.

ADDITIONS

TO THE

LIBRARY OF THE ROYAL SOCIETY OF NEW SOUTH WALES.

DONATIONS—1895.

(The Names of the Donors are in *Italics.*)

TRANSACTIONS, JOURNALS, REPORTS, &c.

ABERDEEN—University. Calendar for the year 1895-96. *The University*

ADELAIDE—Government Geologist. Report on Northern Territory Explorations by H. Y. L. Brown, F.G.S., 1895. *Government Geologist*

Royal Society of South Australia. Transactions, Vol. XVIII., 1893-94; Vol. XIX., Part i., July 1895. *The Society*

ALBANY—New York State Library. Annual Reports (73rd - 76th) of the Regents, 1890-93. Annual Reports (45th, 46th, and 47th) of the Regents of the New York State Museum for 1891, 1892, 1893. Annual Reports (105th - 107th) of the Regents of the University of the State of New York, 1891 - 1893. Bulletin of the New York State Museum, Vol. I., Nos. 1 - 6, 1887-88; Vol. II., Nos. 7 - 10, 1889-90, Vol. III., Nos. 11 - 13, 1893-95. State Library Bulletin, Legislation, Nos. 4 and 5, 1894-95. Additions No. 2, Nov. 1894. Bibliography No. 1, May, 1895. *The Regents*

AMSTERDAM—Koninklijke Akademie van Wetenschappen. Verhandelingen, Tweede Sectie, Deel III., 1894. Verslagen der Zittingen, 1893-94 Jaarboek voor 1893. *The Academy*

Nederlandsche Maatschappij ter bevordering van Nijverheid. Wekelijksche Courant de Nijverheid, Jahrgang I., Nos. 39 - 52, 1893; Jahrgang II., Nos. 1 - 52, 1894; Jahrgang III., Nos. 1 - 13, 1895. *The Association*

AUCKLAND—Auckland Institute and Museum. Annual Report for 1894-95. *The Institute*

BALLARAT—School of Mines and Industries. Calendar for 1895 with Annual Report for 1894. *The Registrar*

BATAVIA—Department van Onderwijs, Erediensten Nijverheid. Pithecanthropus Erectus eine Menschenaehnliche uebergangs form aus Java von Eug. Dubois, 1894. *The Department*

Koninklijke Natuurkundige Vereeniging in Nederl-Indië. Natuurkundig Tijdschrift, Deel LIV. Boekwerken, 1893-94. Naamlijst der Leden op 1 Mei 1895. *The Society*

BALTIMORE—Johns Hopkins University. American Journal of Mathematics, Vol. XIV., No. 4, 1892; Vol. XV., Nos. 1 - 4, 1893; Vol. XVI., Nos. 1 - 3, 1894. American Chemical Journal, Vol. XIV., No. 8, 1892; Vol. XV., Nos. 1 - 8, 1893; Vol. XVI., Nos. 1 - 6, 1894. American Journal of

BALTIMORE—*continued.*

Philology, Vol. XIII., No. 4. 1892; Vol. XIV., Nos. 1 – 4, 1893; Vol. XV., No. 1, 1894. Circulars, Vol. XII., Nos. 104, 115 – 118, 1893-95; Vol. XIV., Nos. 119, 120, 1895. Studies in Historical and Political Science, Vol. X., No. 12, 1892; Vol. XI., Nos. 1 – 12, 1893; Vol. XII., Nos. 1 – 7, 1894. Studies from the Biological Laboratory, Vol. V., Nos. 2 – 4, 1893. *The University*

BERGEN—Bergens Museums. Aarbog for 1893. *The Museum*

BERKELEY—University of California. Bulletin of the Department of Geology, Vol. I., Nos. 5 – 9, pp. 161 – 300, 1894-1895. *The University*

BERLIN—Centralbureau der Internationalen Erdmessung. Verhandlungen der 1894 zu Innsbruck. *The Bureau*

Gesellschaft für Erdkunde. Verhandlungen, Band XXI., Nos. 7 – 10, 1894; Band XXII., Nos. 1 – 3, 1895. Zeitschrift, Band XXIX., 3 – 6, 1894; Band XXX., No. 1, 1895. Bemerkungen über das Klima von Jaluit-Nach Dr. Steinbach. *The Society*

Königlich Geodätisches Instituts. Feier des hundertjahrigen Geburtstages. Jahresbericht des Direktors, 1893 1894. Bemerkungen zu der Schrift. *The Institute*

Königlich Preussische Akademie der Wissenschaften. Sitzungsberichte, Nos. 39 – 53, 1893, with Index and Title, &c.; Nos. 1 – 53, 1894; Nos. 1 – 38, 1895. *The Academy*

Königlich Preussische Meteorologische Instituts. Bericht über die Thatigkeit im Jahre, 1894. Ergebnisse der Gewitter-Beobachtungen im Jahre, 1891. Ergebnisse der Beobachtungen an den Stationen II. und III., Ordnung im Jahre, 1894, Heft 1 and 2; 1895, Heft 1. *The Institute*

BERNE—Département de l' Intérieur de la Confédération Suisse. Graphische Darstellung der Schweizerischen hydrometrischen, Beobachtungen, Bl. I. – XVI., 1894. Tableau graphique des températures de l' air et des hauteurs pluviales, Pl. 1, 2, 3, 1893. Tableau graphique des observations hydrométriques suisses, Pl. I. – XVI., 1894. *The Department*

BIRMINGHAM—Birmingham Natural History and Philosophical Society. Proceedings, Vol. IX., Part 1, Session 1894. *The Society*

Birmingham and Midland Institute. Report of the Council for 1894. Results of Examinations and Award of Prizes 1894. Programme for Session 1895-96. *The Institute*

BOLOGNA—R. Accademia delle Scienze dell'Istituto. Memorie, Ser. 5, Tomo III., 1892. *The Academy*

BONN—Naturhistorischen Vereins der Preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück. Verhandlungen, Jahrgang LI., Folge 5, Band XI., Hälfte 1, 1894; Folge 6, Band I., Hälfte 2, 1894. *The Society*

BOSTON—American Academy of Arts and Sciences. Proceedings, New Ser. Vol. XX., Whole Ser. Vol. XXVIII., 1892 1893; Vol. XXI., Whole Ser. Vol. XXIX., 1893-94. *The Academy*

BOSTON—*continued.*

Boston Society of Natural History. Memoirs, Vol. III., No. 18, 1894; Vol. IV., No. 11, 1893. Proceedings, Vol. XXVI., Parts i., ii., and iii., 1892-94. Occasional Papers—Geology of the Boston Basin by W. O. Crosby, Vol. IV., Parts i. and ii., 1893-94. *The Society*

BREMEN—Meteorologische Station I. Ordnung. Ergebnisse der Meteorologischen Beobachtungen, Jahrgang V., 1894. *The Director*

Naturwissenschaftlicher Verein. Abhandlungen, Band XIII, Heft 2; Band XV., Heft 1, 1895. *The Society*

BRISBANE—Department of Agriculture. Botany Bulletin, Nos. 10–12, 1895. Bulletin, (Second Series) No. 5, April 1895. *The Department*

Department of Mines. Bulletin of the Geological Survey, No. 1, 1895. "

Government Geologist. Annual Progress Report of the Geological Survey for the years 1888 and 1894. Report on the Leichhardt Gold Field and other Mining Centres in the Cloncurry District by W. H. Rands. *Government Geologist*

Government Meteorologist. Table of Rainfall during Oct.–Dec. 1893, Jan.–Dec. 1894. Meteorological Record—Climatological Tables, Oct.–Dec., 1893, Jan.–Dec. 1894. Meteorological Synopsis, Nov.–Dec., 1893, Jan.–Dec. 1894, Jan.–April, 1895. *Government Meteorologist*

Hydraulic Engineer. Report on Water Supply by J. B. Henderson, M. Inst. C.E, 1894. *The Engineer*

Natural History Society of Queensland. Transactions, Vol. I., 1892-3-4. *The Society*

Queensland Acclimatisation Society. Transactions, Vol. I., Part xi., 1895. "

Royal Geographical Society of Australasia. Proceedings and Transactions of the Queensland Branch, Vol. X., Session 1894-95. "

Royal Society of Queensland. Proceedings, Vol. XI., Part i., 1894. "

BRISTOL—Bristol Naturalists' Society. Proceedings, N.S., Vol. VII., Part 3, 1893-94. Annual Report (32nd) and List of Members, 30 April, 1894. "

BROOKVILLE, Ind.—Indiana Academy of Science. Proceedings. 1892, 1893. *The Academy*

BRUNN—Naturforschende Verein. Verhandlungen, Band XXXI., 1892. Bericht der Meteorologischen Commission, Vol. XI., 1891. *The Society*

BRUSSELS—Commissions Royales d'Art et d'Archéologie. Bulletin, Année XXVII.–XXXII., 1888–1893. *The Commission*

BUCHAREST—Institutul Meteorologic al României. Annale, Tomul VII., VIII., Anul 1891-92. Buletinul, July–Dec. 1894. *The Institute*

BUENOS AIRES—Instituto Geografico Argentino. Boletin, Tomo XIII., Cuadernos 7–9, 1892; Tomo XIV., Cuadernos 1–4, 1893; Tomo XV., Cuadernos 1–12, 1894-95; Tomo XVI., Cuadernos 1–2, 1895. "

CAEN—Académie Nationale des Sciences, Arts et Belles-Lettres. Mémoires, 1894 et Tables Décennales 1884 – 1893 incl. *The Academy*

CALCUTTA—Asiatic Society of Bengal. Proceedings, Nos. 7 – 10, 1894, Nos. 1 – 6, 1895. Journal, N.S. Vol. LXI., Part i., Extra Number 1892; Vol. LXIII., Part i., Nos. 3 and 4, Part ii., Nos. 2 – 4, 1894; Vol. LXIV., Part i., No. 1, Part ii., Nos. 1 and 2, 1895. *The Society*

Geological Survey of India. Records, Vol. XXVIII., Parts i. – iii., 1895. *The Director*

CAMBRIDGE—Cambridge Philosophical Society. Proceedings, Vol. VIII., Parts iii., iv., 1893-94. *The Society*

Cambridge Union Society. Annual Report, Sept. 1895. ,,

Public Free Library. Annual Report (38th) 1892-93, (39th) 1893-94. *The Library*

University Library. Annual Report of the Library Syndicate for 1894 and 1895. ,,

CAMBRIDGE, Mass.—Cambridge Entomological Club. *Psyche*, Vol. VII., Nos. 218 – 234, 1894-95. *The Club*

Museum of Comparative Zoölogy. Annual Report of the Curator for 1893-94. Bulletin, Vol. XVI., No. 15, 1895; Vol. XXV., Nos. 9 – 12, 1894-95; Vol. XXVI., Nos. 1, 2, 1894-95; Vol. XXVII., Nos. 1 – 3, 1895; Vol. XXVIII., (Geological Series, Vol. III.) No. 1, July 1895. Memoirs Vol. XVII., No. 3, 1894; Vol. XVIII., 1895. *The Museum*

CARLSRUHE—Technische Hochschule. Programm für das Studienjahr 1894-95. Lektionsplan für das Wintersemester 1894-95. Inaugural-Dissertations (6) 1893-94. *The Director*

CASSEL—Vereins für Naturkunde. Bericht, Vol. XXXIX., 1892 – 1894. *The Society*

CHEMNITZ—Naturwissenschaftliche Gesellschaft. Bericht, Band XII., 1889-92. ,,

CHICAGO—Chicago Academy of Sciences, Bulletin, Vol. I., Nos. 1 – 10, 1883-86; Vol. II., No. 1, 1891. *The Academy*

Field Columbian Museum, Pub. 1, Vol. I., No. 1, 1894. *The Museum*

CHILI—Société Scientifique du Chili. Actes, Tome II., Liv. 4, 1892; Tome III., Liv. 4, 5, 1893; Tome IV., Liv. 2 – 4, 1894. *The Society*

CHRISTIANIA—Association Geodésique Internationale Commission de la Norvége. Resultate der im Sommer 1894 in dem südlichsten Theile Norwegens ausgeführten Pendelbeobachtungen von O. E. Schiötz. Astronomische Beobachtungen, 1895. *The Association*

Norwegische Commission der Europäischen Gradmessung. Resultate der im Sommer 1893 in dem nördlichsten Theile Norwegens ausgefürten Pendelbeobachtungen von O. E. Schiötz. *The Commission*

Université Royale de Norvege. Jahrbuch des Norwegischen Meteorologischen Instituts für 1891 Beskrivelse af En Række Norske Bergarter af Dr. Th. Kjerulf, 1892. *The University*

CHRISTIANIA—*continued.*

Videnskabs-Selskabets. Forhandlinger, Nos. 1–21, 1893, (Complete) *The Society*

CINCINNATI—Cincinnati Society of Natural History. Journal, Vol. XVI., Nos. 2–4, 1893-94; Vol. XVII., Nos. 1–4, 1894-95. „

COLOMBO—Royal Asiatic Society. Index to Journal and Proceedings of the Ceylon Branch, Vol. I.–XI., Nos. 1–41, 1845–1890. „

COPENHAGEN—Société Royale des Antiquaires du Nord. Mémoires, Nouvelle Série, 1893. „

CORDOBA—Academia Nacional de Ciencias. Boletin, Tomo XII., Entrega 2–4, 1891-92; Tomo XIII., Entrega 1–4, 1892-3; Tomo XIV., Entrega 1–2, 1894. *The Academy*

CRACOW—Académie des Sciences. Bulletin International, Nos. 8–10, 1894; Nos. 1, 2, 4, and 5, 1895. „

DENVER—Colorado Scientific Society. Proceedings, Vol. IV., 1891-92-93. Occurrence of Tellurium in oxidized form associated with gold, by Dr. R. Pearce, 1 April, 1895. The sampling and measurement of ore bodies in mine examinations, by E. B. Kirby, 1895. The Recent History and Present Status of Chemistry by Prof. C. S. Palmer. The Determination of Bismuth in Refined Lead and in Lead Bullion by L. G. Eakins. Notes on the Precipitation of the Precious Metals from Cyanide Solutions by means of zinc, No. 1 The non-existence of Cyanide of Zinc in Alkaline Solutions by N. Anderson. The Volcanic Rock of Alum Hill, Boulder County, Colorado, by C. Irving Andrews. Vein Structure in the Enterprise Mine by T. A. Rickard. Ore Deposits of Camp Floyd District, Tooele County, Utah, by R. C. Hills, 1894. A suspected New Mineral from Cripple Creek, by F. C. Knight, 1894. Notes on the Geology of the Western Slope of the Sangre de Cristo Range in Costillo Co., Colo., by E. C. and P. H. van Diest, 1894. The Costilla Meteorite by R. C. Hills, 1895. *The Society*

DES MOINES—Iowa Geological Survey. Annual Report (1st) for 1892, Vol. I., Coal Deposits of Iowa by C. R. Keyes, 1894. Vol. II. Second Annual Report, 1893, Vol. III. *The Survey*

DIJON—Académie des Sciences, Arts et Belles-Lettres. Mémoires, Série 4, Tome IV., Années 1893, 1894. *The Academy*

DRESDEN—K. Säch. Statistische Bureaus. Zeitschrift, Jahrgang XXXIX., Heft 1–4, 1893; Jahrgang XL., Heft 1–4, 1894. *The Bureau*

Vereins für Erdkunde. Jahresbericht, Band XXIV., 1894. *The Society*

DUBLIN—Royal Irish Academy. "Cunningham Memoirs," No. 10, 1894. Proceedings, 3 Ser., Vol. III., No. 3, 1894. Transactions, Vol. XXX., Parts 13, 14, 1894. *The Academy*

EDINBURGH—Botanical Society of Edinburgh. Transactions and Proceedings, Vol. XX., Part i., 1894. *The Society*

Edinburgh Geological Society. Transactions, Vol. VII., Part i., 1894. „

EDINBURGH—*continued.*

Royal Physical Society. Proceedings, Session 1893-94. *The Society*

Royal Scottish Geographical Society. *Scottish Geographical Magazine*, Vol. x., Nos. 9–12, 1894 and Index; Vol. xi., 1–4, 6–9, 1895. Accessions to the Library, Nov. 1, 1893 to Oct. 31, 1894. Classified List of the Principal Papers in Vols. viii.–x. incl. ,,

Scottish Microscopical Society. Proceedings, Session 1893-4. ,,

FLORENCE—Società Africana d'Italia. Bullettino della Sezione Fiorentina, Vol. x., Serie 2, Vol. ii., Fasc. 3–8, 1894-5. ,,

Società Italiana di Antropologia e di Etnologia. Archivio, Vol. xxiv., Fasc. 2, 1804; Vol. xxv., Fasc. 1, 1895. ,,

FORT MONROE—U. S. Artillery School. Journal of the U. S. Artillery, Vol. iii., No. 4, 1894; Vol. iv., Nos. 1, 2, 4, 1895. *The School*

FRANKFURT A M.—Senckenbergische Naturforschende Gesellschaft. Abhandlungen, Band xviii., Heft. 3, 4, 1894-95. Bericht 1894. *The Society*

FREIBURG (Baden)—Naturforschende Gesellschaft. Berichte, viii., 1894. ,,

GEELONG—Gordon Technical College. '*The Geelong Naturalist*,' Vol. iv., Nos. 2–4, 1894-95. *The Wombat*, Vol. i., No. 1, August 1895. *The College*

GENEVA—Institut National Genevois. Bulletin, Tome xxxii., 1894. *The Institute*

GLASGOW—University. Calendar for the year 1895-96. *The University*

GOTTINGEN—Königliche Gesellschaft der Wissenschaften. Nachrichten, Math-phys. Classe, Nos. 3, 4, 1894, Nos. 1, 2, 1895. *The Society*

HAARLEM—Colonial Museum. Bulletin, March, July, 1895. Nuttige Indische Planten door Dr. M. Greshoff, Aflevering 1, [Extra Bulletin, 1894]. *The Museum*

Musée Teyler. Archives, Série 2, Vol. iv., Parts iii., iv., 1894-95. ,,

Société Hollandaise des Sciences. Archives Néerlandaises, des Sciences Exactes et Naturelles, Tome xxviii., Liv. 3–5, 1894-5; Tome xxix., Liv. 1–3, 1895. *The Society*

HALLE A S—K. Leopold-Carol. Deutsche Akademie der Naturforscher. Nova Acta, Vol. lvii.–lxii., 1892–1894. Repertorium, Band i., [Acta, Band i.–x., Nova Acta Band i.–viii.] Leopoldina, Heft 28–30, 1892-93. Katalog der Bibliothek, Lieferung 4, (Band ii., 1) 1893; Lieferung 5, (Band ii., 2) 1894. Geschichte der Bibliothek und Naturaliensammlung von Dr. Oscar Grulich, 1894. *The Academy*

HALIFAX, N.S.—Nova Scotian Institute of Science. Proceedings and Transactions, Second Series, Vol. i., Part iii., Session 1892-93. *The Institute*

HAMBURG—Deutsche Seewarte. Archiv, Jahrgang xvii., 1894, Ergebnisse der Meteorologischen Beobachtungen, Jahr-

HAMBURG—*continued.*

gang XVI., 1893. Jahres-Bericht über Thatigkeit der Deutschen Seewarte, XVII., für das Jahr 1894. Katalog der Bibliothek der Deutschen Seewarte Nachtrag I., 1894. Resultate Meteorologischer Beobachtungen von Deutschen und Holländischen Schiffen für Eingradfelder des Nordatlantischen Ozeans [Quadrat 78] No. XIV., 1894. *The Observatory*

Geographische Gesellschaft. Mittheilungen, Heft 2, 1891-92. *The Society*

Naturhistorische Museum. Mitteilungen, Jahrgang X., Hälfte 2, 1892; Jahrgang XI., 1893. *The Museum*

Naturwissenschaftliche Verein. Abhandlungen aus dem Gebiete der Naturwissenschaften, Band XIII., 1895. Verhandlungen, Folge III., Heft 2, 1894. *The Society*

Vereins für naturwissenschaftliche Unter-haltung. Verhandlungen, Band VIII., 1891 – 1893. "

HAMILTON—Hamilton Association. Journal and Proceedings, No. 10, Session 1893-94. *The Association*

HEIDELBERG—Naturhistorisch-Medicinischer Vereins. Verhandlungen, N.F. Band V., Heft 3, 1894. "

HELSINGFORS—Société des Sciences de Findlande. Acta, Tomus XX., 1895. Bidrag, Häftet, 54 – 56, 1894-95. Ofversigt, Forhandlingar, Vol. XXXVI., 1893-94. Observations Météorologiques Central, 1889-90. Oeservations Météorologiques faites à Helsingfors en 1893. "

HOBART—Department of Mines. Report of the Secretary for Mines for 1894-5. *The Secretary for Mines*

Royal Society of Tasmania. *The Tasmanian Mail*, Vol. XVIII., No. 958, Nov. 30, 1895. *The Society*

HOBOKEN N. J.—Stevens Institute of Technology. Annual Catalogue, 1894-95. *The Institute*

JALAPA—Observatorio Meteorologico Central del Estado de Vera Cruz. Boletin, Jan., Feb., Mar., and Resumen en el año de 1894. *The Observatory*

JENA—Medicinisch-Naturwissenschaftliche Gesellschaft. Jenaische Zeitschrift für Naturwissenschaft, Band XXVIII., N.F. Band XXI., Heft. 4; Band XXIX., N.F. Band XXII., Heft. 1, 2, 1894. *The Society*

KEW—Royal Gardens. Hooker's Icones Plantarum, Fourth Series, Vol. IV., Parts ii. – iv., 1894-95. *The Bentham Trustees*

KINGSTON—Institute of Jamaica. Journal, Vol. II., No. 1, 1894. Jamaica in 1895—A Handbook of Information for intending settlers and others. *The Institute*

KNIN—Société Archéologique Croate. Starohrvatska Prosvjeta. God. I., Br. 1 – 3, 1895. *The Society*

LANSING, Mich.—Michigan Mining School. Reports of the Director for 1890 – 1892. *The School*

LA PLATA—Facultad de Agronomia y Veterinaria. Revista, Nos. 5 – 7, 1895. *The Faculty*

LAUSANNE—Société Vaudoise des Sciences Naturelles. Bulletin 3e S. Vol. XXX., Nos. 115, 116, 1894; Vol. XXXI., No. 117, 1895. *The Society*

LEEDS—Conchological Society of Great Britain and Ireland. Journal, Vol. VII., No. 12. 1894. „

Leeds Philosophical and Literary Society. Annual Report (75th) for 1894-95. „

Yorkshire College. Annual Report (20th) 1893-4. *The College*

LEIPZIG—Königliche Sächsische Gesellschaft der Wissenschaften. Berichte über die Verhandlungen, math-phys. classe, Heft. 2, 3, 1894; Heft. 1 and 4, 1895. *The Society*

Vereins für Erdkunde. Mitteilungen, 1894. Wissenschaftliche Veröffentlichungen, Band II. „

LIÉGE—Société Géologique de Belgique. Annales, Tome XX., Liv. 3, 1892-93; Tome XXI., Liv. 3, 1893-94; Tome XXII., Liv. 1, 1894-95. „

Société Royale des Sciences. Mémoires, Serie 2, Tome XVIII., 1895. „

LITTLE ROCK—Geological Survey of Arkansas. Annual Report for 1891 Vol II., for 1892 Vol. II. *The Survey*

LONDON—Anthropological Institute of Great Britain and Ireland. Journal, Vol. XXIV., Nos. 1–4; Vol. XXV., No. 1, 1894-1895. *The Institute*

British Museum (Natural History). A Monograph of the Mycetozoa by Arthur Lister, F.L.S. *The Museum*

Geological Society. Quarterly Journal, Vol. L., No. 200, 1894; Vol. LI., No. 203, 1895. List of Fellows, &c., Nov. 1, 1894. Geological Literature added to the Society's Library during the half year ended Dec. 1894. *The Society*

Highland and Agricultural Society of Scotland. Transactions, Fifth Series, Vol. VII., 1895. „

India Office. Káfiristàn and its People by G. S. Robertson, C.S.I. *Secretary of State for India*

Institute of Chemistry of Great Britain and Ireland. Proceedings, Parts i. and ii., 1894. Register, 1894–1895, 1895–1896. *The Institute*

Institution of Civil Engineers. Minutes of Proceedings, Vol. CXIX.–CXXII., 1894-95, Parts i.–iv. Charter, By-Laws, and List of Members, Sept. 6, 1895. *The Institution*

Iron and Steel Institute. Journal, Vols. XLV., XLVI., Nos. 1, 2, 1894. Brief Index of Papers in Journal 1869–1894. *The Institute*

Linnean Society. Journal, Botany, Vol. XXX., Nos. 209, 211, 1894-95; Zoology, Vol. XXV., Nos. 158, 161, 1894-95. Proceedings, from Nov. 1893 to June 1894. List of Fellows, 1894-95. *The Society*

Meteorological Office. Meteorological Observations at Stations of the Second Order for the year 1890. Report of the Meteorological Council to the Royal Society for the year ending 31 March, 1894. *The Council*

LONDON—*continued.*

Mineralogical Society. Mineralogical Magazine and Journal Vol. x., Nos. 45 and 48, 1892-94; Vol. xi., Nos. 49, 50, 1895. *The Society*

Pharmaceutical Society of Great Britain. Pharmaceutical Journal, 3 Ser. Vol. xxv., Nos. 1266-1317, 1894-95; 4 Ser. Vol. i., Nos. 1319-1321, 1895. Calendar 1895. *„*

Physical Society of London. Proceedings, Vol. xiii., Parts i.–x., Nos. 51–60, 1894-95. List of Officers and Members, April 2, 1895. *„*

Quekett Microscopical Club. Journal, Ser. 2., Vol. v., No. 35, 1894; Vol. vi., No. 36, 1895. *The Club*

Royal Agricultural Society of England. Journal, Third Series, Vol. v., Parts iii., iv., 1894; Vol. vi., Parts i.–iii., 1895. *The Society*

Royal Astronomical Society. Monthly Notices, Vol. liv., No. 9, 1894; Vol. lv., Nos. 1–8, 1894-95. *„*

Royal College of Physicians. List of Fellows, Members, Extra-Licentiates and Licentiates, 1895. *The College*

Royal College of Surgeons of England. Calendar, July 12, 1894, July 11, 1895. *„*

Royal Colonial Institute. Proceedings, Vol. xxvi., 1894-95. Catalogue of the Library, 1895. *The Institute*

Royal Geographical Society. The Geographical Journal, Vol. iv., Nos. 4–6, 1894; Vol. v., Nos. 1–6, 1895; Vol. vi., Nos. 1–4, 1895. *The Society*

Royal Historical Society. Transactions, New Series, Vol. viii., 1894. Gibbon Commemoration 1794–1894. *„*

Royal Institution of Great Britain. Proceedings, Vol. xiv., Part ii., No. 88, March 1895. *The Institution*

Royal Meteorological Society. Quarterly Journal, Vol. xx., No. 92, 1894; Vol. xxi., Nos. 93, 94, 1895. Meteorological Record, Vol. xiv., Nos. 53–55, 1894. *The Society*

Royal Microscopical Society. Journal, Parts v., vi., Nos. 102, 103, 1894; Parts ii., iv., Nos. 105, 107, 1895. *„*

Royal Society. Indian Meteorological Memoirs, Vol. vii., Parts i. and ii., 1894. Philosophical Transactions, Vol. clxxxv., Parts i. and ii., each A and B, 1894. Proceedings, Vol. lvi. and lvii., 1894-95. List of Fellows, 30 Nov., 1894. *„*

Royal United Service Institution. Journal, Vol. xxxviii., Nos. 199–202, 1894; Vol. xxxix., Nos. 203–209, 211, 1895. *The Institution*

Sanitary Institute. Journal. Vol xv., Parts i.–iv., 1894-95; Vol. xvi., Parts i., ii., 1895. *The Institute*

South Kensington Museum. Calendar for 1895. Catalogues of Percy Collection of Metallurgy; Science Library; Machinery, Models, &c., Part i.; Special Loan Collection of Scientific Apparatus, 1876. Report upon action of Light on Water Colours. Report upon Analysis of Oriental Metal Work, &c. by Prof. W. C. Roberts-Austen C.B., F.R.S. *The Museum*

Zoological Society of London. Proceedings, Parts iii., iv., 1894; Parts i., ii., 1895. Transactions, Vol. xiii., Parts ix., x., 1894-95. *The Society*

LUBECK—Geographische Gesellschaft und des Naturhistorisches Museums. Mitteilungen, Zweite Reihe, Heft 7, 8, 1895. *The Museum*

LUXEMBOURG—L'Institut Royal Grand-Ducal. Publications, Section des Sciences Naturelles et Mathématiques, Tome XXIII., 1894. *The Institute*

MADRAS—Government Observatory. Madras Meridian Circle Observations, Vol. VIII., 1883 – 1887. Errata, Vols. I. – VI. *The Observatory*

Madras Government Museum. Bulletin, Nos. 1 – 3, 1894-95. *The Museum*

MADISON, Wis.—Wisconsin Academy of Sciences, Arts, and Letters. Transactions, Vol. IX., Parts i., ii., 1892-93. *The Academy*

MANCHESTER—Conchological Society. Journal, Vol. VIII., Nos. 1 – 4, 1895. *The Society*

Manchester Geological Society. Transactions, Vol. XXIII., Parts i. – ix., 1894-95. "

Manchester Literary and Philosophical Society. Memoirs and Proceedings, 4 Series, Vol. VIII., Nos. 3, 4, 1893-94; Vol. IX., Nos. 1 – 6, 1894-95. "

MARBURG—Königliche Universitäts-Bibliothek. Inaugural Addresses (73) 15 August, 1893-94. *The University*

Gesellschaft zur Beförderung der gesammten Naturwissenschaften. Sitzungsberichte, Jahrgang 1893. *The Society*

MARSEILLES—Faculté des Sciences de Marseille. Annales, Tome III., Fasc. Supplémentaire 1893; Tome IV., Fasc. 1 – 3, 1894. Sur l' Existence et la propagation des oscillations électro-magnétiques dans l' air, par M. A. Perot. *The Faculty*

Institut Botanico-Géologique Colonial. Annales, Ser. 1, Année I., Vol. I., 1893. *The Institute*

MELBOURNE—*Australasian Journal of Pharmacy*, Vol. IX., Nos. 106 – 108, 1894; Vol. X., Nos. 109 – 119, 1895. *The Publishers*

Broken Hill Proprietary Co. Ld. Reports and Statements of Account for Half Years ending 30 Nov. 1894 and 31 May 1895. *The Secretary*

Department of Mines. Annual Report of the Secretary for Mines for 1894. Report on the loss of gold in the reduction of auriferous veinstone in Victoria, by H. Rosales, M.E., F.G.S., 1895. Reports on the Victorian Coal Fields, Nos. 3 and 4, by James Stirling. *The Department*

Field Naturalists' Club of Victoria. *The Victorian Naturalist*, Vol. XI., Nos. 7 – 12, 1894-95; Vol. XII., Nos. 1 – 5, 7, 1895. *The Club*

Public Library, Museums, and National Gallery of Victoria. A Descriptive Catalogue of the specimens in the Industrial and Technological Museum, Melbourne, illustrating the Economic Woods of Victoria. Select Extra-Tropical Plants by Baron Ferd. von Mueller, Ninth Edition, 1895. *The Trustees*

MELBOURNE—*continued.*

Royal Society of Victoria. Transactions of the Victorian Institute, Vol. I., Sessions 1854-55. Transactions of the Philosophical Society of Victoria, Vol. I., 1855. Transactions and Proceedings of the Royal Society of Victoria Vol. VIII., Part i., 1867; N.S. Vol. VII., 1894. Transactions, Vol. IV., 1895. *The Society*

MÉRIDA—Universidad de los Andes. Annuario, Tomo Tercero, 31 Dec. 1893. *The University*

MERIDEN Conn.—Meriden Scientific Association. Transactions Vol. V., 1893. *The Association*

METZ—Verein für Erdkunde zu Metz. Jahresbericht, Band XVII., 1894-95. *The Society*

MEXICO—Observatorio Astronómico Nacional de Tacubaya. Anuario, Año XV., 1895. Boletin, Tomo I., Nos. 18–21, 1895. *The Observatory*

Sociedad Cientifica "Antonio Alzate." Memorias y Revista, Tomo VII., Nos. 11, 12, 1893-94. *The Society*

MILAN—Reale Istituto Lombardo di Scienze e Lettere. Rendiconti, Serie 2. Vol. XXV., 1892; Vol. XXVI., 1893. Indice Generale 1803–1888. *The Institute*

Società Italiana di Scienze Naturali. Atti, Vol. XXXV., Fasc. 1, 2, 1895. *The Society*

MINNEAPOLIS—Geological and Natural History Survey of Minnesota. First Report of the State Zoölogist, Zoölogical Series, Vol. I., 1892. *The Survey*

Minnesota Academy of Natural Sciences. Occasional Papers, Vol. I., No. 1, 1894. *The Academy*

MIRFIELD—Yorkshire Geological and Polytechnic Society. Proceedings, New Series, Vol. XII., Parts 4 and 5, 1894. *The Society*

MODENA—Regia Accademia di Scienze, Lettere ed Arti. Memorie, Serie II., Vol. IX., 1893. Opere inviate alla R. Accademia 1892, 1893. *The Academy*

MONTEVIDEO—Société Météorologique de l'Uruguay. Résumé des Observations Pluviométriques faites pendant la saison d'été de l'année 1895 Jan.–Mar. *The Society*

MONTPELLIER—Académie des Sciences et Lettres. Mémories, Série 2, Tome I., Nos. 3 and 4, 1893; Tome II., No. 1, 1894. *The Academy*

MONTREAL—Natural History Society of Montreal. The Canadian Record of Science, Vol. V., No. 8, 1893. *The Society*

Royal Society of Canada. Proceedings and Transactions, Vol. XII., 1894, and General Index, Vols. I.–XII. "

MOSCOW—Observatoire Météorologique de l'Université Impériale de Moscow. Meteorological Observations, Jan., Feb., March, 1895. *The Observatory*

Société Impériale des Naturalistes. Bulletin, N.S. Vol. VIII., Nos. 2–4, 1894; Vol. IX., Nos. 1, 2, 1895. *The Society*

MULHOUSE—Société Industrielle de Mulhouse. Bulletin, Vol. LXIV., Oct.–Dec., 1894; Vol. LXV., Jan.–June, 1895. Programme des Prix, 29 Mai, 1895. "

MUNICH—Bayerische Botanische Gesellschaft, Berichte, Band III., 1893. *The Society*

Königlich Bayerische Akademie der Wissenschaften. Abhandlungen der Math-phys. Classe, Band XVIII., Abth. 3, 1895. Sitzungsberichte, Band XXIII., Heft 3, 1893; Band XXIV., Heft 1-3, 1894. Ueber die Bedentung wissenschaftlicher Ballonfahrten von L. Sohncke, 1894. *The Academy*

NANTES—Société des Sciences Naturelles de l'Ouest de la France. Bulletin, Tome IV., Trimestre 2-4, 1894; Tome V., Trimestre 1, 1895. *The Society*

NAPLES—Società Reale di Napoli. Rendiconto dell' Accademia delle Scienze Fisiche e Matematiche, Ser. 2, Vol. VIII., Fasc. 8-12, 1894; Ser. 3, Vol. I., Fasc. 1-7, 1895. ,,

Zoologische Station zu Neapel. Mittheilungen, Band XI., Heft 3, 1894. *The Director*

NEWCASTLE-UPON-TYNE—Natural History Society of Northumberland, Durham, and Newcastle-upon-Tyne. Transactions, Vol. XI., Part ii., 1894. *The Society*

North of England Institute of Mining and Mechanical Engineers. Report of the Proceedings of the Flameless Explosives Committee, Parts i., ii., Air and Combustible Gases by A. C. Kayll. Transactions, Vol. XLIV., Part i.-iv., 1894-95. *The Institute*

NEW HAVEN—Connecticut Academy of Arts and Sciences. Transactions, Vol. IX., Part ii., 1895. *The Academy*

NEW YORK—American Chemical Society. Journal, Vol. XVI., Nos. 10-12, 1894; Vol. XVII., Nos. 1-10, 1895. *The Society*

American Geographical Society. Bulletin, Vol. XXVI., Nos. 3 and 4, Parts i. and ii., 1894; Vol. XXVII., Nos. i., ii., 1895. ,,

American Institute of Mining Engineers. Transactions, Vol. XXIV., 1894. *The Institute*

American Museum of Natural History. Bulletin, Vol. I., 1881-86; Vol. II., 1887-90; Vol. V., 1893; Vol. VI., 1894. Annual Report of the President &c., for the year 1893. *The Museum*

New York Academy of Sciences. Annals, Vol. VIII., Nos. 4-12, 1894-95; Indexes to Vols. VI. and VII. *The Academy*

New York Microscopical Society. Journal, Vol. X., No. 4, 1894; Vol. XI., Nos. 1-3, 1895. *The Society*

OTTAWA—Geological Survey of Canada. Annual Report, New Series, Vol. VI., 1892-93. *The Survey*

OXFORD—Radcliffe Library. Catalogue of Books added during 1894. *The Trustees*

Radcliffe Observatory. Catalogue of 6,424 Stars for the Epoch 1890 by E. J. Stone, M.A., F.R.S. ,,

PARIS—Académie des Sciences de l'Institut de France. Comptes Rendus, Tome CXIX., Nos. 12-27, 1894; Tome CXX., Nos. 1-25; Tome CXXI., Nos. 1-13, 1895. *The Academy*

PARIS—*continued.*

Comptoir Géologique de Paris. *Annuaire Géologique Universel*, Tome IX., pp. 565–612, 1892; Tome X., Fasc. 2, 1893. Exposition publique et temporaire des Actualités Géologiques (2 Ser. 1894) *The Editor*

Ecole d' Anthropologie de Paris. Revue Mensuelle, Année IV., Nos. 9–12, 1894. Bulletin, No. 3, Juillet–Sept. 1895. *The Director*

Ecole Nationale des Mines de Paris. Statistique de l' Industrie Minérale et des appareils à vapeur en France et en Algérie pour l' année 1893. *Ministère des Travaux Publics*

Ecole Polytechnique. Journal, Cahier 63, 64, 1893-94. *The Director*

Feuille des Jeunes Naturalistes. Revue Mensuelle d' Histoire Naturelle, 3 Ser. Année 24, No. 288, 1894; 3 Ser. Année 25, Nos. 289–300, 1894-95. *The Editor*

L' Observatoire de Paris. Rapport Annuel pour l' année, 1894. *The Observatory*

Museum d' Histoire Naturelle. Bulletin, Nos. 1–3, 1895. *The Museum*

Revue de l' Aéronautique, Tome V., 1892; Tome VI., Liv. 1 and 3, 1893. *The Editor*

Société d' Anthropologie. Bulletins, Serie 4, Tome V., Nos. 2–9, 1894. Mémoires, Serie 3, Tome I., Fasc. 2, 1894. *The Society*

Société de Biologie. Comptes Rendus, Serie 10, Tome I., Nos. 25–35, 1894-95; Ser. 10, Tome II., Nos. 1–27, 1895. „

Société d' Encouragement pour l' Industrie Nationale. Bulletin, 4 Série, Tome IX., 1894. „

Société Entomologique de France. Bulletin, Vol. LXII., 1893. „

Société Française de Minéralogie. Bulletin, Tome XVII., Nos. 7, 8, 1894; Tome XVIII., Nos. 1–6, 1895. „

Société Française de Physique. Bulletin Bimensuel, Nos. 50–52, 1894; Nos. 53–67, 1895. Séances, Année 1894 Fasc. 3, 4; 1895, Fasc. 1. „

Société de Géographie. Bulletin, Ser. 7, Tome XV., Trimestre 2–4, 1894; Tome XVI., Trimestre 1, 2, 1895. Comptes Rendus, Nos. 15–19, 1894; Nos. 1–3, 7–12, 1895. „

Société Géologique de France. Bulletin, Serie 3, Tome XXI., No. 6, 1893; Tome XXII., No. 6–9, 1894; Tome XXIII., Nos. 1–3, 1895. Compte-Rendu des Séances, 3 Ser., Tome XXII., Nos. 14–18, 1894. „

Société Zoologique de France. Bulletin, Tome XIX., 1894. Mémoires, Tome VII., 1894. „

PENZANCE—Royal Geological Society of Cornwall. Transactions, Vol. XI., Part ix., 1894. Laws and Rules. „

PHILADELPHIA—Academy of Natural Sciences. Proceedings, Parts ii. and iii., 1893; Parts i.–iii., 1894; Part i., 1895. *The Academy*

American Entomological Society. Transactions, Vol. XXI., Nos. 3, 4, 1894; Vol. XXII., Nos. 1, 2, 1895. *The Society*

American Philosophical Society. Proceedings, Vol. XXXI., No. 142, 1893; Vol. XXXII., No. 143, 1893; Vol. XXXIII., Nos. 144–146, 1894. List of Surviving Members, 5 Jan. 1894. „

PHILADELPHIA—*continued.*

Franklin Institute. Journal, Vol. CXXXVIII., Nos. 826–828, 1894; Vol. CXXXIX., Nos. 829–834, 1895; CXL., Nos. 835, 837, 838, 1895. *The Institute*

Wagner Free Institute of Science. Transactions, Vol. III., Part iii., 1895. "

Zoological Society. Annual Report (23rd) of the Board of Directors, April 25, 1895. *The Society*

PISA—Società Toscana di Scienze Naturali. Atti, Processi Verbali, Vol. IX., pp. 133–242, 1894-95. "

PLYMOUTH—Plymouth Institution and Devon and Cornwall Natural History Society. Annual Report and Transactions, Vol. XI., Part iv., 1893-94. "

PORT LOUIS—Royal Alfred Observatory. Results of Meteorological Observations taken during the year 1893. *The Observatory*

POTSDAM—K. Preuss. Geodätisches Institutes. Astronomisch-Geodätische Arbeiten I. Ordnung. Telegraphische Längenbestimmungen in 1890, 1891, und 1893. Untersuchungen über den Selbstregistrirenden Universalpegel zu Swinemünde-System Seibt-Fuess. von Prof. A. Westphal, 1895. Zenitdistanzen zur bestimmung der höhenlage der Nordsee-Inseln Helgoland Neuwerk und Wangeroog sowie des Leuchtturmes auf Roter Sand über den festlands funkten Cuxhaven und Schillig. 4° Berlin, 1895. *The Institute*

PRAGUE—Königl. Böhm. Gesellschaft der Wissenschaften. Jahresbericht, für das Jahr. 1892 and 1893. Sitzungsberichte, math.-naturw. classe, 1892 and 1893; philos-histor.-philolog. classe 1892 and 1893. *The Society*

RIO DE JANEIRO—Observatorio. Annuario 1893 and 1894. *The Observatory*

Museu Nacional de Rio de Janeiro. Archivos, Vol. VIII. *The Museum*

ROCHESTER, N.Y.—Geological Society of America. Bulletin, Vols. IV.–VI., 1893-95. List of Officers and Fellows for 1894. *The Society*

ROME—Accademia Pontificia de Nuovi Lincei. Atti, compilati dal segretario, Anno XLVII., Sessione 2, 3, 5–7, 1894; Anno XLVIII., Sessione 1–6, 1895. *The Academy*

Ministero dei Lavori Publblici. Giornale del Genio Civile, Anno XXXII., Fasc. 8–12, 1894; Anno XXXIII., Fasc. 1–6, 1895. *Minister of Public Instruction, Rome*

R. Accademia dei Lincei. Atti, Serie 5, Rendiconti, Vol. III. Fasc. 6–12, Semestre 2, 1894; Vol. IV., Fasc. 1–12, Semestre 1, 1895: Vol. V., Fasc. 1–5, Semestre 2, 1895. Rendiconto dell adunanza solenne del 9 Giugno 1895. *The Academy*

R. Comitato Geologico d' Italia. Bollettino, Vol. XXV., Nos 3, 4, 1894; Vol. XXVI., Nos. 1, 2, 1895. *The Committee*

Società Editrice Dante Alighieri (Via Convertite 8). Revista Geografica Italiana, Annata II., Fasc. 5, 6, 1895. Memorie, Vol. V., Parte i., 1895. *The Society*

Società Geografica Italiana. Bollettino, Ser. 3, Vol. VII., Fasc. 9–12, 1894; Ser. 3, Vol. VIII., Fasc. 1–9, 1895. "

ROME—*continued.*
Ufficio Centrale Meteorologico e Geodinamico Italiano. Annali, Serie 2, Vol. XII., Parte ii., 1890. *The Director*

SACRAMENTO (Cal.)—Lick Observatory. Publications of the Lick Observatory of the University of California, Vol. II., 1894; Vol IV., 1895. *The Observatory*

ST. ANDREWS—University. Calendar for the year 1895-96. *The Senate*

ST. LOUIS—Academy of Science of St. Louis. Transactions, Vol. VI., Nos. 9 - 16, 1893-94. *The Academy*

Missouri Botanical Garden. Annual Report (5th) 1894. *The Director*

ST. PETERSBURG—Académie Impériale des Sciences. Bulletin, N.S., Vol. IV. (XXXVI.) Nos. 1, 2, 1893-94; Serie 5, Tome I., Nos. 1 - 4, 1894, Tome II., Nos. 1 - 4, 1895. Mémoires, Serie 7, Tome XXXIX., Part ii., 1893; Tome XLI., Nos. 2 - 9, 1893; Tome XLII., Nos. 1 - 12, 1894. *The Academy*

Comité Géologique—Institut des Mines. Bulletins, Tome XII., Nos. 8 - 9, 1893; Tome XIII., Nos. 1 - 9, 1894 and Supplement; Tome XIV., Nos. 1 - 5, 1895. Mémoires, Tome VIII., Nos. 2, 3; Tome IX., Nos. 3, 4; Tome X., No. 3, Tome XIV., Nos. 1, 3, 1895. *The Committee*

Russisch-Kaiserlich Mineralogische Gesellschaft. Verhandlungen, Ser. 2, Band XXXI., 1894. *The Society*

SALEM—American Association for the Advancement of Science. Proceedings, Vol. XLII., 1893, Madison Meeting; Vol. XLIII., 1894, Brooklyn Meeting. *The Association*

Essex Institute. Bulletin, Vol. XXVI., Nos. 1 - 12, 1894. Historical Collections, Vol. XXX., Jan. - Dec., 1892. *The Institute*

SAN FRANCISCO—California Academy of Sciences. Procéedings, Vol. IV., Parts i. and ii., 1894-95. Memoirs, Vol. II., No. 4, 1895. *The Academy*

California State Mining Bureau. Twelfth Report of the State Mineralogist (second biennial) two years ending Sept. 15, 1894. *The Bureau*

SAN SALVADOR—Observatorio Astronómico y Meteorológico. Observaciones Meteorologicas del año de 1892, 1893, 1894. *The Observatory*

SCRANTON, Pa.—The Colliery Engineer Co. *The Colliery Engineer and Metal Miner*, Vol. XV., Nos. 3 - 12, 1894-95; Vol. XVI., Nos. 1 - 3, 1895. *The Proprietors*

SOMERVILLE, Mass.—Tufts College. Tufts College Studies, Nos. 1, 2, 3, 1894. *The College*

STAVANGER—Museum. Aarsberetning for 1893. *The Museum*

STOCKHOLM—Kongl. Svenska Vetenskaps-Akademiens. Handlingar, Bandet XXV., Häftet 2, 1892. Bihang, Bandet XIX., Afd. 1 - 4, 1894. Lefnadsteckningar, Band III., Häfte 2, 1894. Ofversigt, Vol. LI., 1894. Accessionskatalog, 8, 9, 1893-94. Om Sveriges zoologiska hafsstation Kristineberg af Hjalmar Théel. *The Academy*

STRASSBURG, i. E.—Centralstelle des Meteorologischen Landesdienstes in Elsass-Lothringen. Ergebnisse der Meteorologischen Beobachtungen im Reichsland Elsass-Lothringen im Jahre 1893. *The Director*

STUTTGART—Königliches Statistische Landesamt. Württembergische, Heft 1 – 3. 1894. *The 'Landesamt'*

Vereins für Vaterländische Naturkunde in Württemberg. Jahreshefte, Band L., Jahrgang 1894. *The Society*

SYDNEY—Australian Museum. Report of the Trustees for the year 1894. Records, Vol. II., No. 6, 1895. *The Trustees*

Department of Mines and Agriculture. *Agricultural Gazette of New South Wales*, Vol. V., Parts x. – xii., 1894; Vol. VI., Parts i. – x., 1895. Annual Report for 1894. Memoirs of the Geological Survey of N. S. Wales—Palæontology Nos. 8, 9. Records of the Geological Survey of N. S. Wales, Vol. IV., Parts iii., iv., 1895. Notes on the Commercial Timbers of N. S. Wales by J. H. Maiden, F.L.S. &c. The Flowering Plants and Ferns of N. S. Wales, Part i., by J. H. Maiden, F.L.S., &c. and W. S. Campbell. *The Department*

Department of Public Instruction. Report of the Minister of Public Instruction, 1894. Technical Education Branch, Calendar 1895. *The New South Wales Educational Gazette*, Vol. IV., Nos. 6 – 12; Vol. V., Nos. 1 – 6, 1894-95. ,,

Engineering Association of New South Wales. Minutes of Proceedings, Vol. VIII., 1893. *The Association*

Government Printer. The Statutes of New South Wales (Public and Private) passed during the Session of 1894 1895. *The Government Printer*

Government Statistician. Statistical Register for 1893 and previous years (complete), and Parts vi., viii. – xi.; for 1894 and previous years, Parts i. – viii. A Statistical Survey of New South Wales, 1893-94. Statistics of the Seven Colonies of Australasia, 1861 – 1894. Wealth and Progress of New South Wales, 1894, 8th issue, Vol. I. *The Government Statistician*

Institution of Surveyors, New South Wales. *The Surveyor*, Vol. VIII., Nos. 11 and 12, 1894; Vol. VIII., Nos. 1 - 11, 1895. *The Institution*

Linnean Society of New South Wales. Proceedings, Second Series, Vol. x., Parts i., ii., 1895. Abstract of Proceedings, Nov. 1894; March - Sept., Nov., 1895. *The Society*

New South Wales Board of Health. Antitoxic Serum for the cure of Diphtheria, 1895. Coast Hospital, Little Bay, Report for 1894. Dairies Supervision Act, Report on administration of, for the year 1894. Leprosy in New South Wales, Appendix to Report for 1894. Maintenance of Sick Paupers, Report on Vote for 1894. Typhoid Fever in Sydney and Suburbs from 1876 to 1894 (inclusive). Vaccination, Report for 1894. Vessels arriving at and leaving ports of New South Wales, Returns respecting, for 1894. *The President*

New South Wales Medical Board. Register of Medical Practitioners for 1895. *The Secretary*

Observatory. Recent Measures of Double Stars made at Sydney by H. C. Russell, B.A., F.R.S. Results of Rain, River, and Evaporation Observations made in New South Wales, during 1893. *The Observatory*

SYDNEY—*continued.*

Sydney Free Public Library. Report from Trustees for 1894. *The Trustees*

University. Calendar of the Sydney University for the year 1895. *The University*

TACUBAYA—Observatorio Astronómico Nacional. Boletin, Tomo I., Núm. 22, 1895. *The Observatory*

TAIPING—*Perak Government Gazette*, Vol. VII., Nos. 21–26, 1894; Vol. VIII., Nos. 1–26, 1895. *Secretary to the Government*

TOKIO—Asiatic Society of Japan. Transactions, Vol. XXII., Part ii., Sept. 1894. General Index, Vols. I.–XXIII., April, 1895. *The Society*

Imperial University of Japan. Calendar 1893-94. Journal of the College of Science, Vol. VII., Parts ii.–v., 1894; Vol. VIII., Parts i., 1895. *The University*

TORONTO—University. Calendar for 1895-96. „

TOULOUSE—Académie des Sciences, Inscriptions et Belles-Lettres. Mémoires, Serie 9, Tome VI., 1894. *The Academy*

TRIESTE—Museo Civico di Storia Naturale. Atti, Vol. IX., 1895. *The Museum*

Osservatorio Astronomico-Meteorologico. Rapporto Annuale Vol. IX., per l'anno 1892. *The Observatory*

TUNIS—Institut de Carthage. Revue Tunisienne, Année I., No. 1, 1894. *The Institute*

TURIN—Osservatorio della R. Università. Osservazioni Meteorologiche fatte nell' anno 1894. *The Observatory*

R. Accademia delle Scienze di Torino. Atti, Vols. XIV., XV., XVII.–XXII., XXIV.–XXIX., 1878-94; Vol. XXX., Disp. 1–11, 1894-95. *The Academy*

VENICE—Reale Istituto Veneto di Scienze, Lettere, ed Arti. Atti, Serie 7, Tomo III., Disp. 4–10, and Appendices 1 and 2, 1891-92; Tomo IV., Disp. 1–10, 1892-93; Tomo V., Disp. 1–3, 1893-94. *The Institute*

VIENNA—Anthropologische Gesellschaft. Mittheilungen, Band XXIV. (N.F. Bd. XIV.) Heft 5, 6, 1894; Band XXV. (N.F. Bd. XV.) Heft 1–3, 1895. *The Society*

Kaiserliche Akademie der Wissenschaften. Sitzungsberichte, math.-naturw. Classe—

Abth.	I.,	Band	CII.,	Nos. 1–10,	1893
„	II*a*,	„	CII.,	„ 1–10,	„
„	II*b*,	„	CII.,	„ 1–10,	„
„	III.,	„	CII.,	„ 1–10,	„
„	I.,	„	CIII.,	„ 1–3,	1894.
„	II*a*,	„	CIII.,	„ 1–5,	„
„	II*b*,	„	CIII.,	„ 1–3,	„
„	III.,	„	CIII.,	„ 1–4,	„

The Academy

K. K. Central-Anstalt für Meteorologie und Erdmagnetismus. Jahrbücher (Officielle Publication) N.F. Band XXIX., Jahrgang, 1892. *The Institute*

K. K. Geographische Gesellschaft. Mittheilungen, Band XXXVI., (N.F. XXVI.) 1893. *The Society*

VIENNA—*continued.*

K. K. Geologische Reichsanstalt. Jahrbuch, Band XLI., Heft. 4, 1891; Band XLIII., Heft. 2–4, 1893; Band XLIV. Heft. 1, 2, 1894. Verhandlungen, Nos. 6–10, 1893; Nos. 10–18, 1894; Nos. 1–7, 1895. *The "Reichsanstalt"*

K. K. Gradmessungs-Bureau. Astronomische Arbeiten, Band VI., 1894. *The Bureau*

K. K. Gradmessungs-Commission. Verhandlungen, Protokoll 11, 12 April, 1894. *The Commission*

K. K. Naturhistorische Hofmuseums. Annalen, Band IX., Nos. 1–4, 1894. ***The Museum***

K. und K. Reichs-Kriegs-Ministerium "Marine Section." Relative Schwerebestimmungen durch Pendelbeobachtungen, 1892–1894. ***The Department***

K. K. Zoologisch-Botanische Gesellschaft. Verhandlungen, Band XLIII., Quartal 3, 4, 1893; Band XLIV., Quartal 1–4, 1894; Band XLV., Heft 1–7, 1895. *The Society*

Section für Naturkunde des Osterreichischen-Touristen Club. Mittheilungen, Jahrgang III., 1891; Jahrgang VI., 1894. ***The Section***

WASHINGTON—American Historical Association. Annual Report for the year 1893. *The Association*

Bureau of Ethnology. Annual Report (9th–12th) 1887-88 to 1890-91. An ancient quarry in Indian territory, by W. H. Holmes. Archeologic investigations in James and Potomac Valleys by Gerard Fowke. Bibliography of the Salishan Languages by J. C. Pilling, 1893. Bibliography of the Wakashan Languages by J. C. Pilling. Chinook Texts by Franz Boas. Contributions to North American Ethnology, Vol. IX., 1893. List of the publications of the Bureau of Ethnology by F. W. Hodge, 1894. The Maya Year by Cyrus Thomas. The Pamunkey Indians of Virginia by J. G. Pollard. *The Bureau*

Chief of Engineers, U.S. Army. Analytical and Topical Index to the Reports, Vol. III., 1888–1892. Annual Report for 1894 (in six parts). *The Department*

Commissioner of Education. Report for the year 1891-92, 2 Vols., Whole Nos. 211, 212. *The Commissioner*

U.S. Department of Agriculture. Division of Ornithology and Mammalogy—North American Fauna, No. 8. Division of Statistics N.S. Report Nos. 113–116, 118, 119. Farmers' Bulletin, Nos. 20, 21, 24, 1894. Monthly Weather Review Aug.–Decr. 1894; Jan., Feb., 1895, and Annual Summary for 1894. Report of the Chief of the Weather Bureau for 1893. Report of the Secretary of Agriculture, 1893. Section of Foreign Markets–Bulletin, No. 4, 1895; Circular, Nos. 1, 2, 3, 1895. *The Department*

Department of the Interior (Census Office). Compendium of the Eleventh Census, 1890, Part ii. Report on Indians taxed and Indians not taxed in the United States (Except Alaska); Report on Insurance Business in the United States, Part I. Fire, Marine, and Inland Insurance at the Eleventh Census, 1890. Report on Population and Resources of Alaska at the Eleventh Census, 1890.

"

WASHINGTON—*continued.*

U.S. Geological Survey. Annual Report (12th) 1890-91, Parts i., ii.; (13th) 1891-92, Parts 1, 2, 3. Bulletin, Nos. 97–117, 1893-94. Mineral Resources of the United States, 1892-93. Monographs, Vols. XIX., XXI., XXII., 1892-93. *The Survey*

Director of the Mint. Annual Report (22nd) for the fiscal year ended June 30, 1894. *The Director*

National Academy of Sciences. Memoirs, Vol. VI., 1893. *The Academy*

Navy Department—Office of Naval Intelligence. Notes on the year's Naval Progress, July 1894. *The Department*

Smithsonian Institution. Annual Report of the Board of Regents for 1891, 1892, and to July 1893. Circular No. 44, 1894. Diary of a Journey through Mongolia and Tibet in 1891 and 1892 by W. W. Rockhill. Report of the U.S. National Museum 1891-92. Smithsonian Contributions to Knowledge, No. 884—[The Internal Work of the Wind by S. P. Langley]. Smithsonian Miscellaneous Collections, Nol. XXXV., No. 854; Vol. XXXVIII., No. 970, 1894. *The Institution*

Treasury Department. Annual Report of the Secretary of the Treasury on the state of the Finances for the year 1894. *The Department*

U.S. Coast and Geodetic Survey. Bulletin, No. 34, 1895 Report of the Superintendent for the fiscal year ending June 30, 1892, Part ii. *The Survey*

U.S. Hydrographic Office Notice to Mariners, Nos. 27–52, 1894, and Index to Vol; Nos. 1–37, 1895. Pilot Chart of the North Atlantic Ocean, Aug.–Dec. 1894; Jan., May–Sept., 1895. Charts—No. 1474, North America United States and Canada, Lake Superior; No. 1476, North America United States and Canada, Lake Huron and Georgian Bay; No. 1477, North America United States and Canada, Lakes Erie and Ontario; Nos. 1494, West Coast of Lower California, San Ignacio Lagoon. *U. S. Hydrographer*

War Department. Annual Report of the Secretary of War for the year 1893, Vols. I., II. (Parts i.–vi.) III., IV. *The Department*

WELLINGTON, N.Z.—Department of Lands and Survey. Report of the Survey Department, N.Z. for 1892-93. Report of the Department of Lands and Survey N.Z, for 1894-95. The Land Districts, 1894. *The Department*

Mining Geologist. Older auriferous drifts of Central Otago, 1894. *Mining Department*

New Zealand Institute. Transactions and Proceedings, Vol. XXVII., (N.S. Vol. X.) 1894. *The Institute*

Polynesian Society. Journal, Vol. III., No. 4, 1894; Vol. IV., Nos. 1–3, 1895. *The Society*

WINNIPEG—Historical and Scientific Society of Manitoba. Transactions, Nos. 45–47, 1894. Annual Report for the year 1893. "

ZURICH—Naturforschende Gesellschaft. Vierteljahrschrift, Jahrgang XXXIX., Heft 3, 4, 1894; Jahrgang XL., Heft 1, 2, 1895. Neujahrsblatt, No. 97, 1895. "

Miscellaneous.

(Names of Donors are in *Italics*.)

Acland, Sir Henry W., Bart K.C.B., F.R.S.—The Unveiling of the Statue of Sydenham in the Oxford Museum, Aug. 9, 1894, by the Marquis of Salisbury, K.G., with an Address by. *The Author*

Annual Report of the City Engineer—City of Newton, Mass. for year 1892. *The Engineer*

Australasian Association for the Advancement of Science. Report of the Fifth Meeting held at Adelaide, Sept., 1893. *T. F. Wiesener*

Australasian Medical Gazette, Vol. II., No. 8, 1883; Vol. XIII., No. 1, 1894. *The Publisher*

Bickerton, Prof. A. W.—Some recent evidence in favour of impact, 1894. Copy of letters sent to "*Nature*," on partial impact, 1879. A New Story of the Stars. *The Author*

Bonaparte, Prince Roland—Démocratic Suisse, 1890. Assemblées démocratiques en Suisse, 1890. Les Variations Périodiques des Glaciers Francais, 1891. Une Excursion en Corse. ,,

Bourke, Capt. John G.—Folk-Foods of the Rio Grande Valley and of Northern Mexico. Popular Medicine, Customs and Superstitions of the Rio Grande. The Laws of Spain in their application to the American Indians. ,,

Brown, Robert—Roberti Brownii Prodromus Florae Novae-Hollandiae et Insulae Van-Diemen (German Reprint) 4° Londini, 1810. *F. B. W. Woolrych*

Cameron, Alex. M.—Light as the Interpretation of the Law of Gravity, 1895. *The Publishers*

Council, Edward—Maxims: political, philosophical and moral, (2nd Edition) *The Author*

Crehore, Dr. A. C., and Squier, Dr. G. O.—Experiments with a new Polarizing Photo-Chronograph, applied to the Measurement of the Velocity of Projectiles, 1895. *The Authors*

Cudmore, P.—Buchanan's Conspiracy. The Nicaragua Canal and Reciprocity. 8° New York, 1892. *The Author*

Cunow, Heinrich—Die Uerwandtschafts-Organisation der Australal-negar. ,,

Dana, Prof. James D.—On Serpentine pseudomorphs, and other kinds, from the Tilly Foster Iron Mine, Putman Co., New York. Phenomena of the Glacial and Champlain periods about the mouth of the Connecticut Valley, that is, in the New Haven region. Origin of Coral Reefs and Islands. On the Volcanoes and Volcanic Phenomena of the Hawaiian Islands by James D. Dana, with a paper on the Petrography of the Islands by Edward S. Dana. Areas of continental progress in North America, and the influence of the conditions of these areas on the work carried forward within them. Sedgwick and Murchison, Cambrian and Silurian.

Dana, Prof. James D.—*continued.*

Archæan-axes of Eastern North America. Rocky Mountain Protaxis and the Post-Cretaceous Mountain-making along its course. Some of the features of non-volcanic Igneous Ejections as illustrated in the four "Rocks" of the New Haven Region—West Rock, Pine Rock, Mill Rock, and East Rock. On Percival's map of the Jura-Trias trap-belts of Central Connecticut, with observations on the upturning or mountain-making disturbance of the formation. On Subdivisions in Archæan History. Bibliography of James D. Dana. Crustacea, Parts i. and ii., with a Folio Atlas of 96 Plates; 4° Philadelphia, 1852. U.S. Exploring Expedition, Vol. XIII., Parts i. and ii., and Atlas—Crustacea. *The Author*

Dresdner Journal, No. 107, 11 Mai, 1894. *The Publisher*

Fitzgerald, Mrs. P. F.—A Treatise on the Principle of Sufficient Reason, 8° London, 1887. *The Author*

Fritsche, Dr. H.—Die magnetischen Localabweichungen bei Moskau und ihre Beziehungen zur dortigen Local-Attraction. ,,

Geinitz, H, B.—Bohrversuche für eine neue Wasserwerks-aulage auf Tolkewitzer Flur bei Dresden. ,,

Geographische Zeitschrift heraus. von Dr. Alfred Hettner, Jahrgang I., Heft 1, 1895. *The Editor*

Hinrichs, Gustavus, M.D., LL.D.—Contributions to Atom-Mechanics *The Author*

Janet, Charles—Etudes sur les Fourmis, Les Guepes and Les Abeilles, Notes 10 and 11. ,,

Katalog der Ausstellung des x Deutschen Geographentages. 8° Stuttgart, 1893. *The Publishers*

K. K. Gradmessungs-Bureau, Astronomische Arbeiten, Band IV., 1892. *J. W. Chard*

Klossovsky, Prof. A.—Organisation de l'Etude Climatérique Spéciale de la Russie et problèms de la Meteorologie agricole. Distribution annuelle des orages à la surface du globe terrestre. *The Author*

Kosmopolan, No. 25, Nov. 1, 1895. *The Publishers*

Kuntze, Dr. Otto—Geogenetische Beiträge, 1895. *The Author*

Mayr, Dr. George von—Referat-Statistif der beutschen Binnenwanderungen. ,,

Medical Magazine, Vol, I., No. 11, May 1893 (4° London). *The Publisher*

Medical Press, N.S., Vol. LX., No. 2941, 18 Sept. 1895. ,,

Minerva, Año II., Núm 1, Marzo 1894, 8° Puebla. ,,

Modigliani, Dott. Elio—portati dal-Danielli Dott Jacopo studiati dal Crani ed ossa lunghe di Abitanti dell Isola d' Engauge 1894. *The Author*

Mullins, G. L., M.A., M.D.—Notes on Hydatid Disease in New South Wales, 1895. Notes on Phthisis in New South Wales and other Australasian Colonies. Epidemic Diseases and their prevention in the Eastern Suburbs of Sydney, 1895. ,,

Nangle, James—Roof Coverings. *The Author*

Nowlan, James—Darwin's Theory of the Genesis of the Moon. ,,

Oliver, Charles A., M.D.—A new series of Berlin wools for the scientific detection of subnormal colour-perception, (colour blindness). Description of a revolving astigmatic disk. The comparative action of sulphate of daturia and of sulphate of hyoscyamia upon the iris and ciliary muscle. Third Annual Report of the Ophthalmological Department of the Staie Hospital at Norristown, Pa. for the year 1888. ,,

Osterreichische gradmessungs-Commission Verhandlungen, Protokoll 11, 13, April 1894. *The Commission*

Peek, Cuthbert E., M.A., F.S.A.—Meteorological Observations at the Rousdon Observatory, Devon, for the years 1893 and 1894, Vols. X. and XI. *The Author*

Puga, Guillermo B. Y.—Tempestades del Fin del Invierno, 1895. ,,

Ramond, G.—Geologie Asie et Océanie, 1891, ,,

Ramond, G. et Martel, E.—A note sur la cloche gypseuse de Taverny. ,,

Revue Thérapeutique des Alcaloides, Année IV., No. 37, Dec. 1893, Paris. *The Publisher*

Smith, J. McGarvie—Investigation of the composition of the air in the Sewers of Sydney, with special reference to the presence of germs. *The Author*

Società d' Esplorazione Commerciale in Africa, Anno X., Fasc 5 1895. *The Soccety*

The Locomotive, New Ser., Vol. XVI., No. 8, 1895. *The Publisher*

Todd, Sir C., K.C.M.G., M.A., F.R.S.—Meteorological Work in Australia: A Review. *The Anthor*

Transactions of the Devonshire Association, Vols. X. – XIX., 1878 – 1887, 8° Plymouth, 1885-87. Extra Volume The Devonshire Domesday, Parts 2, 3, 4, 1885-87. *Rev. Dr. Harris, M.A.*

White, Rev. James S., M.A., LL.D.—Democracy in Theory and Practice. The Land Tax and the reasons in justification considered. *The Author*

Wilde, Henry, F.R.S.—On the Multiple Proportions of the Atomic Weights of Elementary Substances in relation to the unit of Hydrogen. 1895. On the evidence afforded by Bode's law of a permanent contraction of the Radii Vectores of the Planetary Orbits. ,,

Winn, Jm, M.D., M.R.C.P.—An exposition of the fallacies of the Materialistic Theory of Physiological Psychology, 1894. ,,

---

DONATIONS TO THE SOCIETY'S CABINETS, &C.

Photograph (framed)—Distinguished Men of Science of Great Britain living in the years 1807-8. *Hon. H. E. Kater*, M.L.C.

Photograph of a flash of lightning two miles long taken at the Sydney Observatory, 16 September, 1895.
H. C. Russell, B.A., C.M.G., F.R.S.

Periodicals Purchased in 1895.

American Journal of Science and Art, (Silliman).
American Monthly Microscopical Journal.
Analyst.
Annales des Chimie et de Physique.
Annales des Mines.
Annals of Natural History.
Astronomische Nachrichten.
Athenæum.
Australian Mining Standard.

British Medical Journal.
Building and Engineering Journal of Australia and New Zealand.

Chemical News.
Curtis's Botanical Magazine.

Dingler's Polytechnisches Journal.

Electrical Review.
Engineer.
Engineering.
Engineering and Mining Journal.
Engineering Record.
English Mechanic.

Fresenius Zeitschrift für Analytische Chemie.

Geological Magazine.

Industries and Iron.

Journal and Transactions of the Photographic Society.
Journal de Médecine.
Journal of Anatomy and Physiology.
Journal of Botany.
Journal of Morphology.
Journal of the Chemical Society.
Journal of the Institution of Electrical Engineers.
Journal of the Royal Asiatic Society of Great Britain and Ireland.
Journal of the Society of Chemical Industry.

Knowledge.

L' Aéronaute.
Lancet.

Medical Record of New York.
Mining Journal.

Nature.
Notes and Queries.

Observatory.

Petermann's Ergänzungsheft.
Petermann's Geographischen Mittheilungen.
Philosophical Magazine.
Proceedings of the Geologists' Association.

Quarterly Journal of Microscopical Science.

Sanitary Engineer.
Sanitary Record.
Science.
Science Gossip.
Scientific American.
Scientific American Supplement.

Zoologist.

Books Purchased in 1895.

American Institution of Electrical Engineers, Vols. I. - IX.
Annals of British Geology by Blake, Vols. I. - IV., 1890-93.
Australian Handbook, 1895.

Biedermann's, Dr. R.—Technisch-Chemisches, Jahrbuch, Vol. XVI., 1893-4; Vol. XVII., 1894-5.
Braithwaite, R.—British Moss Flora, Part 16.
Braithwaite, J.—The Retrospect of Medicine, Vol. CX., 1894: Vols. CXI., CXII, 1895.
British Association—Report 1894.
Buckler, W.—Larvæ of the British Butterflies and Moths, Vol. VI., Part iii. (*Ray Soc.*)

Challenger Report—Summary of Results with Appendices.

Fresenius Zeitschrift für Analytische Chemie, Index, Band XXI. - XXX., 1882 - 1891.

Henslow, Rev. George—The Origin of Plant Structures, 1895. (*Inter. Sci. Soc.*, Vol. LXXVII.)

Index Kewensis, Parts i. - iv.
International Scientific Series, Vol. LXXVII.

Jahresbericht der Technologie, 1894.

Marie, Dr. Pierre—Lectures on Diseases of the Spinal Cord. (*New Syd. Soc.* Vol. CLII.)
Medico-Chirurgical Society, Transactions Vol. LXXVII, 1894.

Nautical Almanack for 1898.
New Sydenham Society's Publication, Vol. CLII., &c, Atlas of Pathology. Fasc. 9.

Obstetrical Society—Transactions, Vol. XXXVI., 1894.

Palæontographical Society, Vol. XLVIII.
Pathological Society—Transactions, Vol. XLV., 1894.

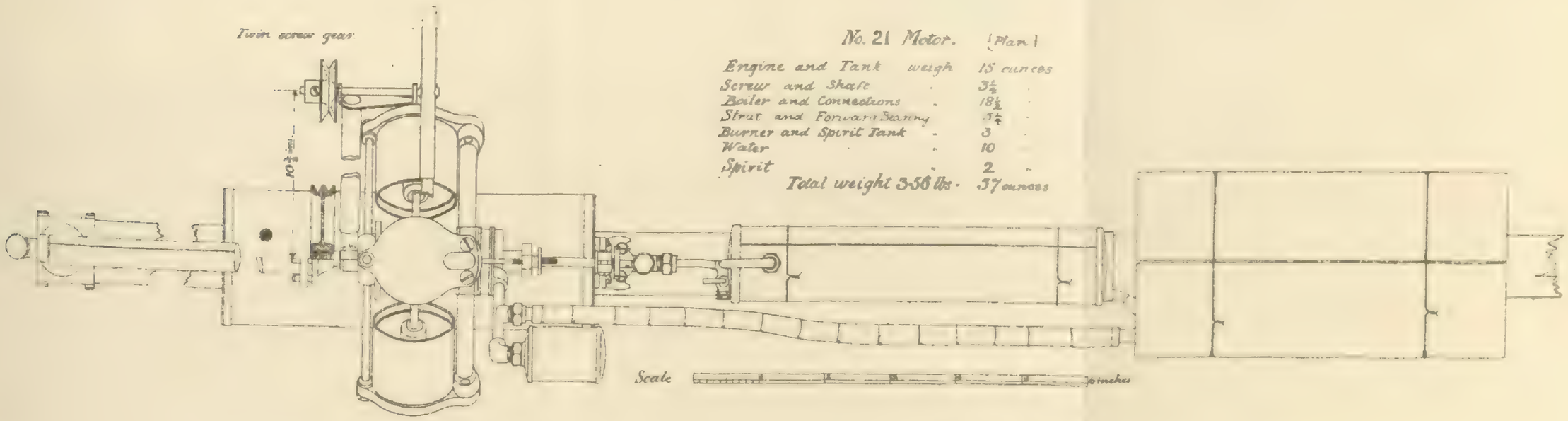
Ray Society's Publications, Vol. VI., 1893.

Sands' Directory, 1895.
Schmidt, Adolf.—Atlas der Diatomaceen-Kunde, Hef. 50.

Whitaker's Almanack, 1896.

Year Book of Scientific and Learned Societies, 1895.

No. 21 Motor. (Elevation) *Diagram. I.*



No. 21 Motor. (Plan)

Engine and Tank	weigh	15 ounces
Screw and Shaft	.	3½ .
Boiler and Connections	.	18½ .
Strut and Forward Bearing	.	5½ .
Burner and Spirit Tank	.	3 .
Water	.	10 .
Spirit	.	2 .
Total weight 3·56 lbs.		57 ounces

Diagram. II.

Diagram III.

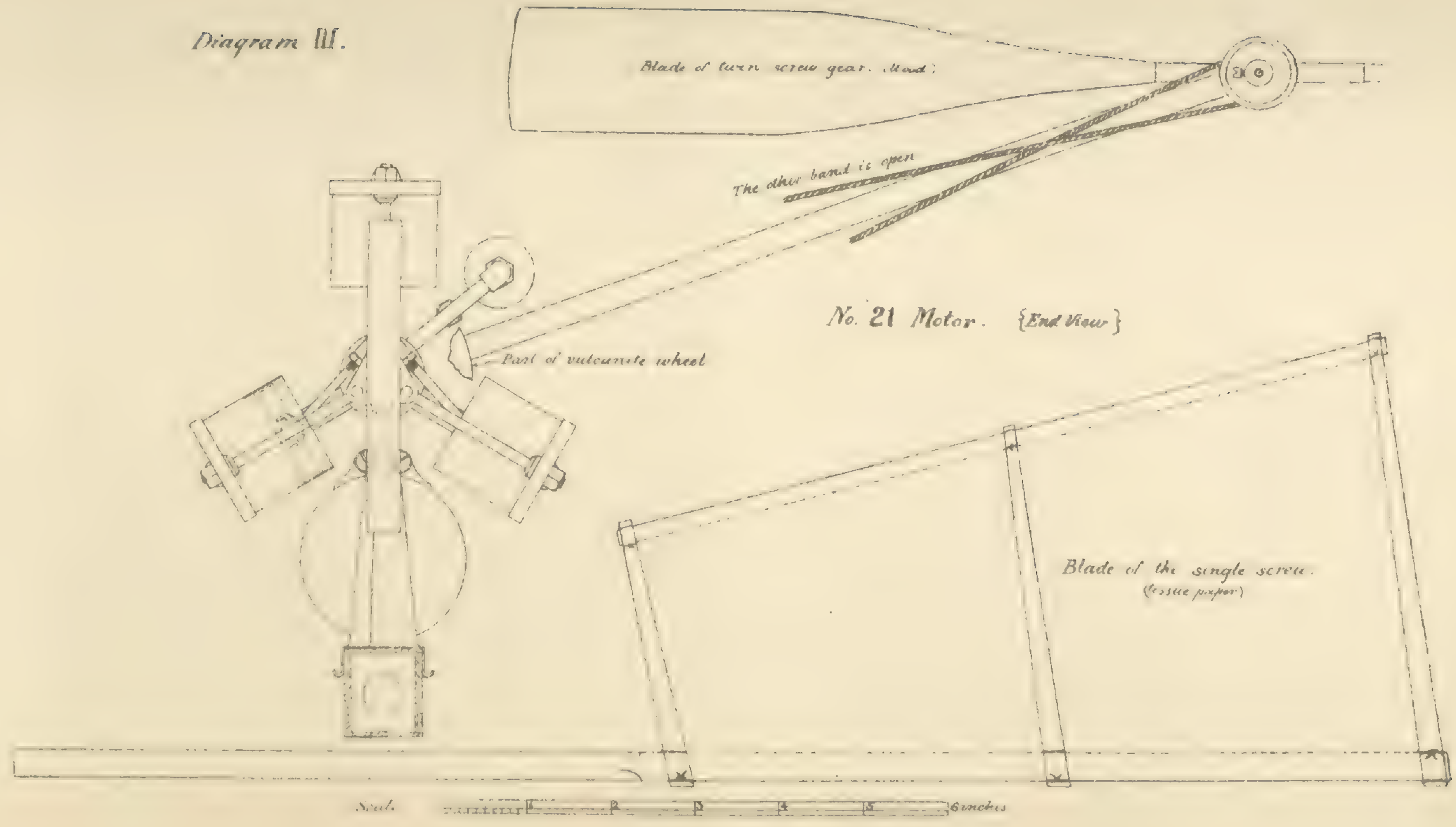
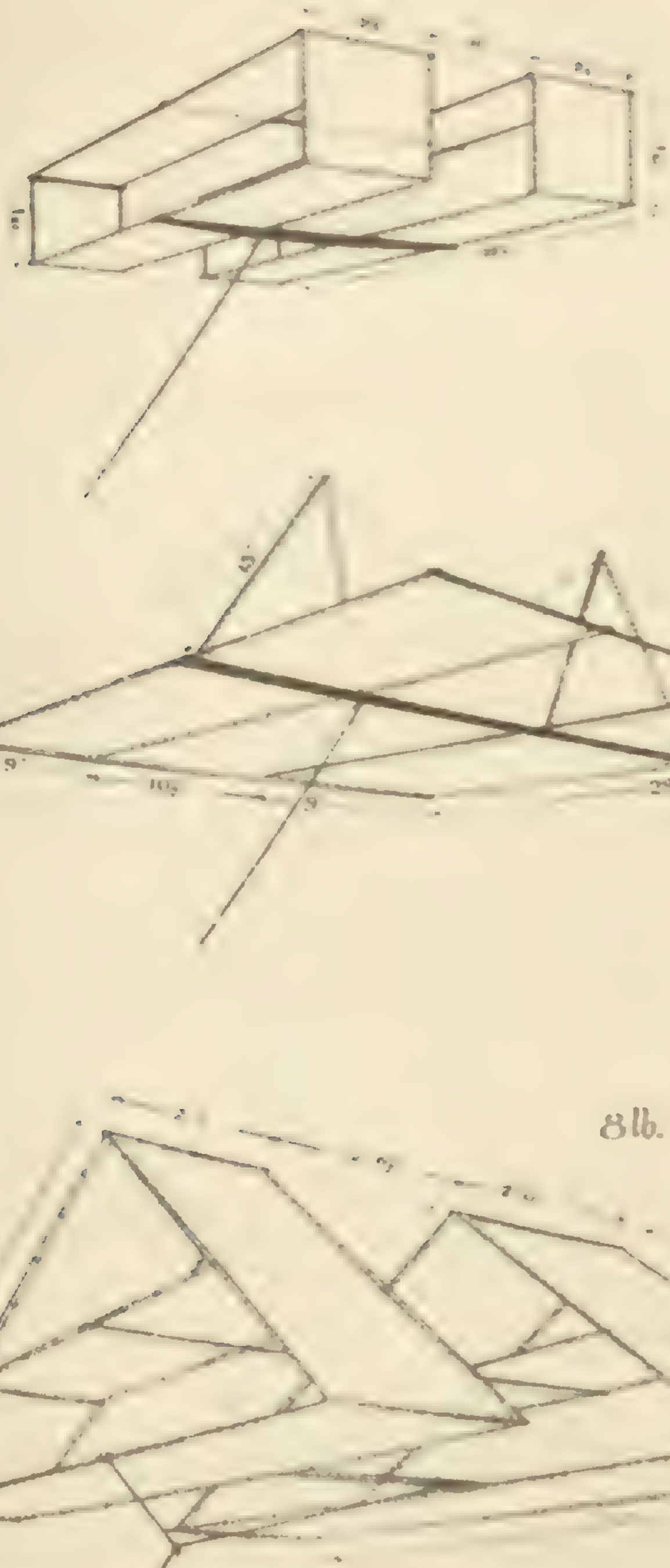


Plate III.



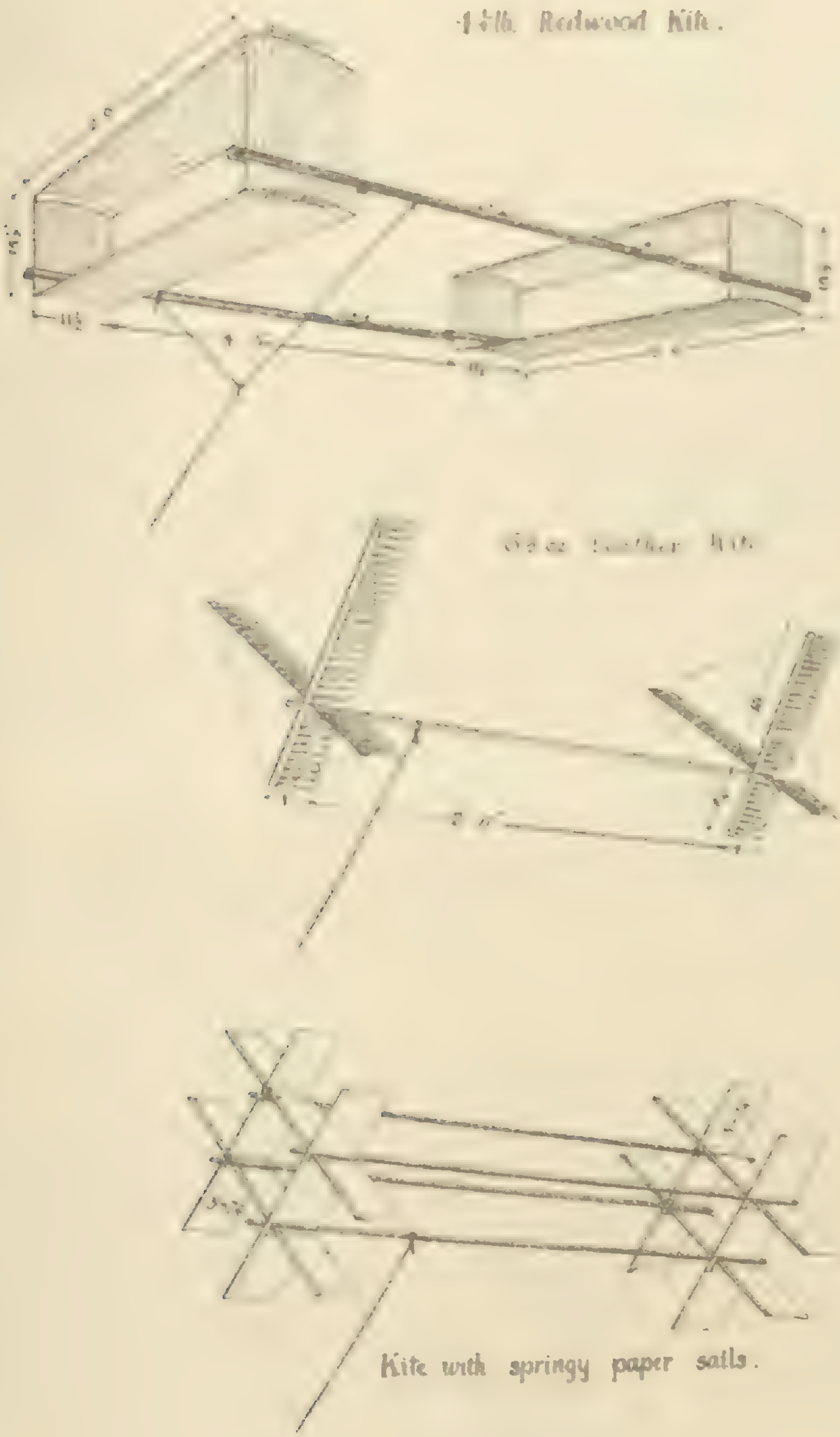
9¾ oz. Kite.

4 oz Kite.

8lb. Calico Kite.

4½ oz. Kite.

Diagram IV.



Kite with springy paper sails.

Diagram. V.

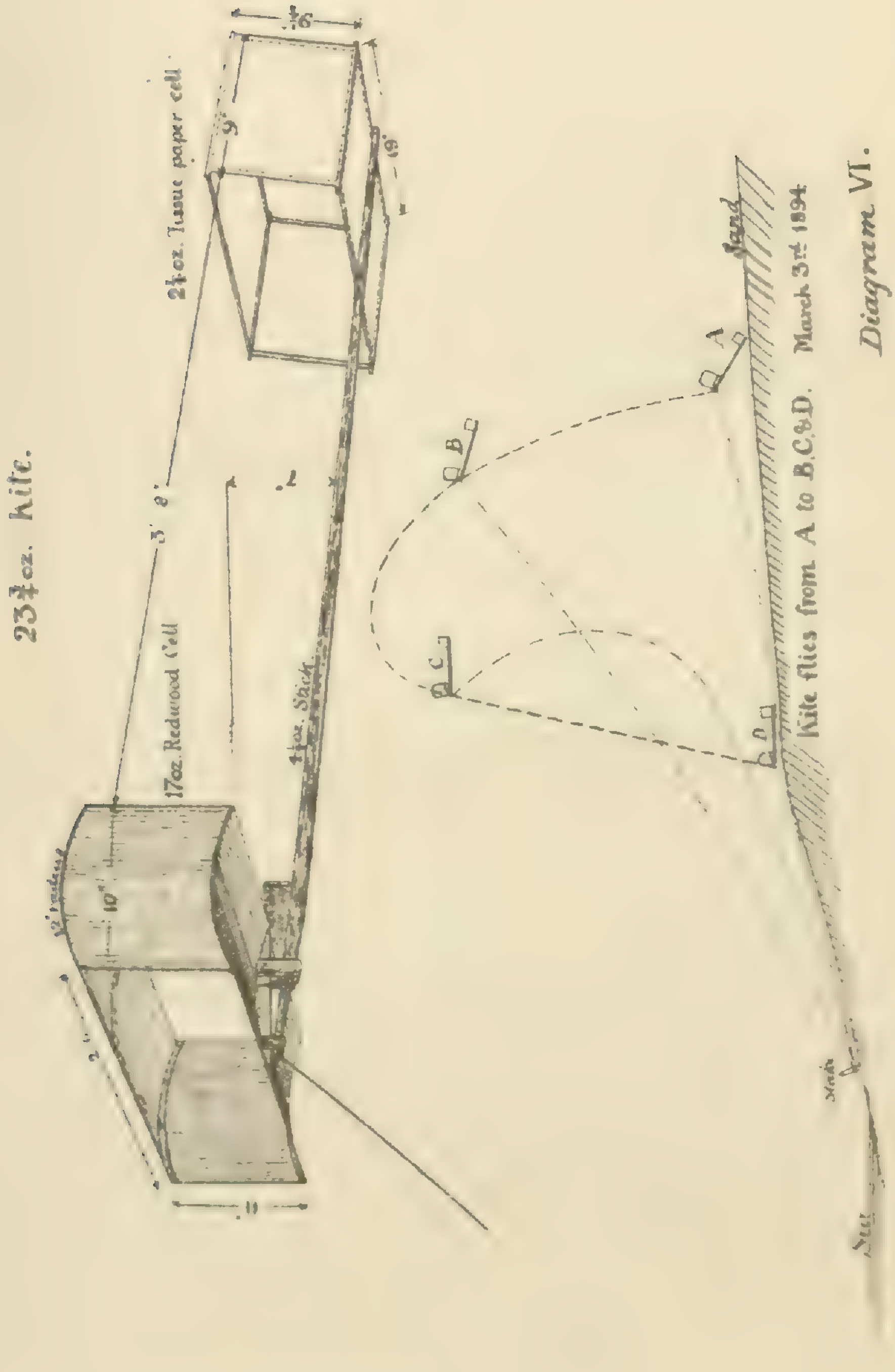
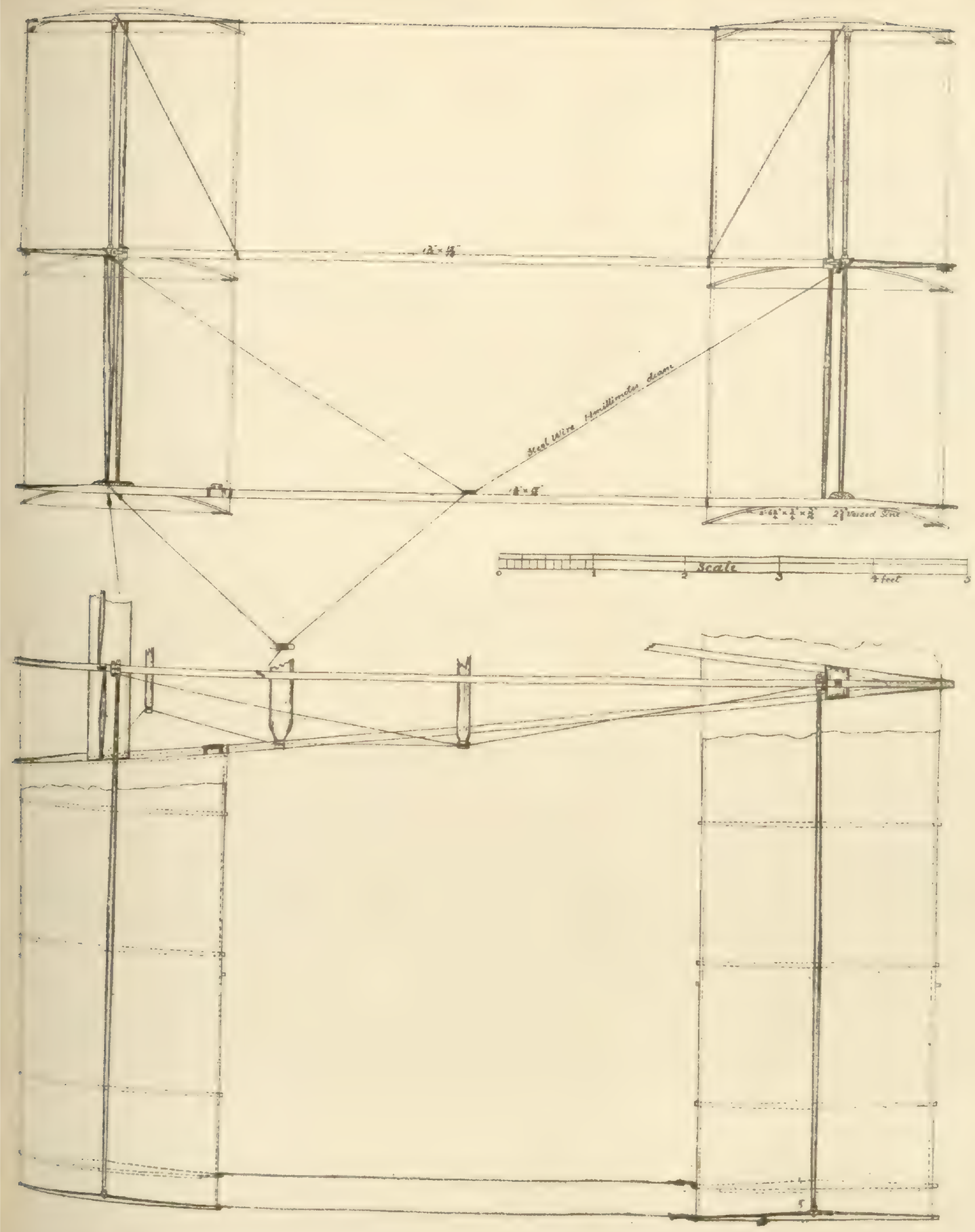

23¾ oz. Kite.
2¼ oz. Tissue paper cell
17 oz. Redwood Cell
4¼ oz. Stick
Kite flies from A to B, C & D.
March 3rd 1894
Sand
A
B
C
D

Diagram VI.



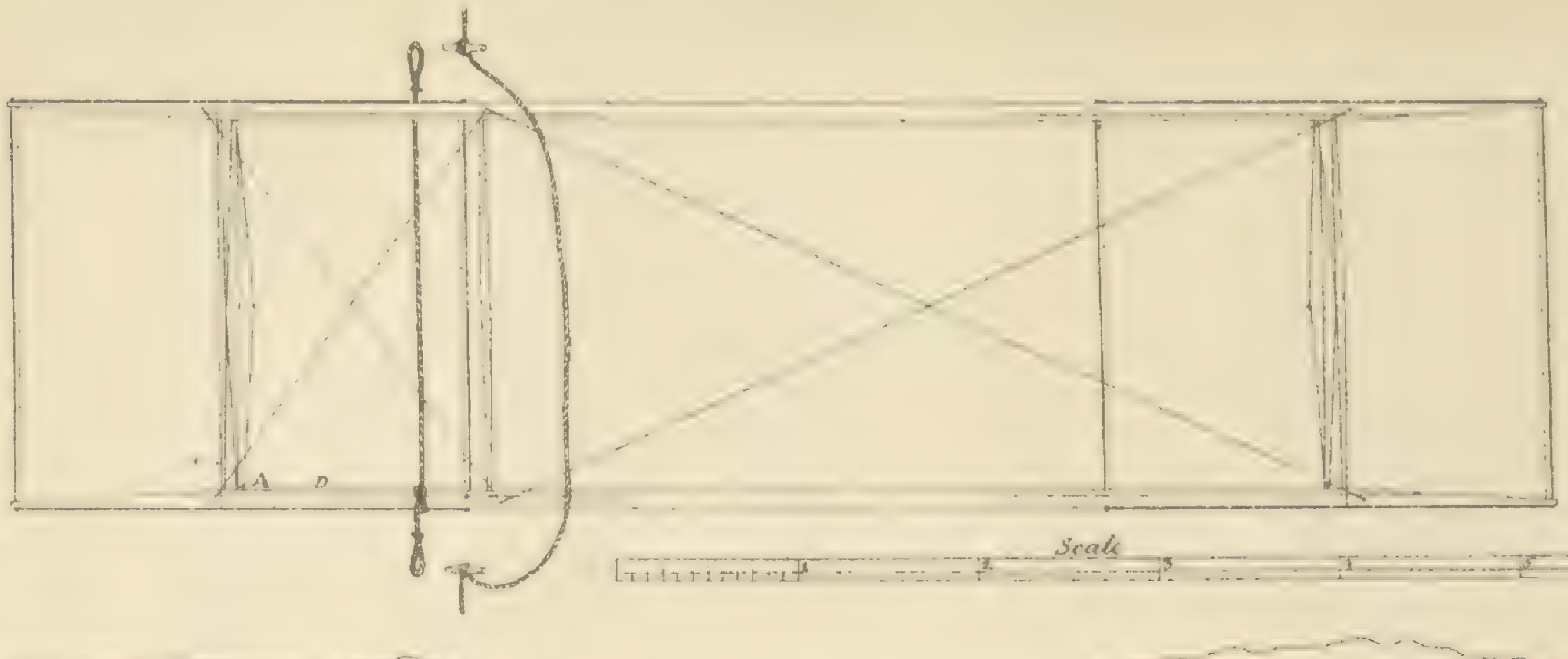
158 feet Cellular Kite

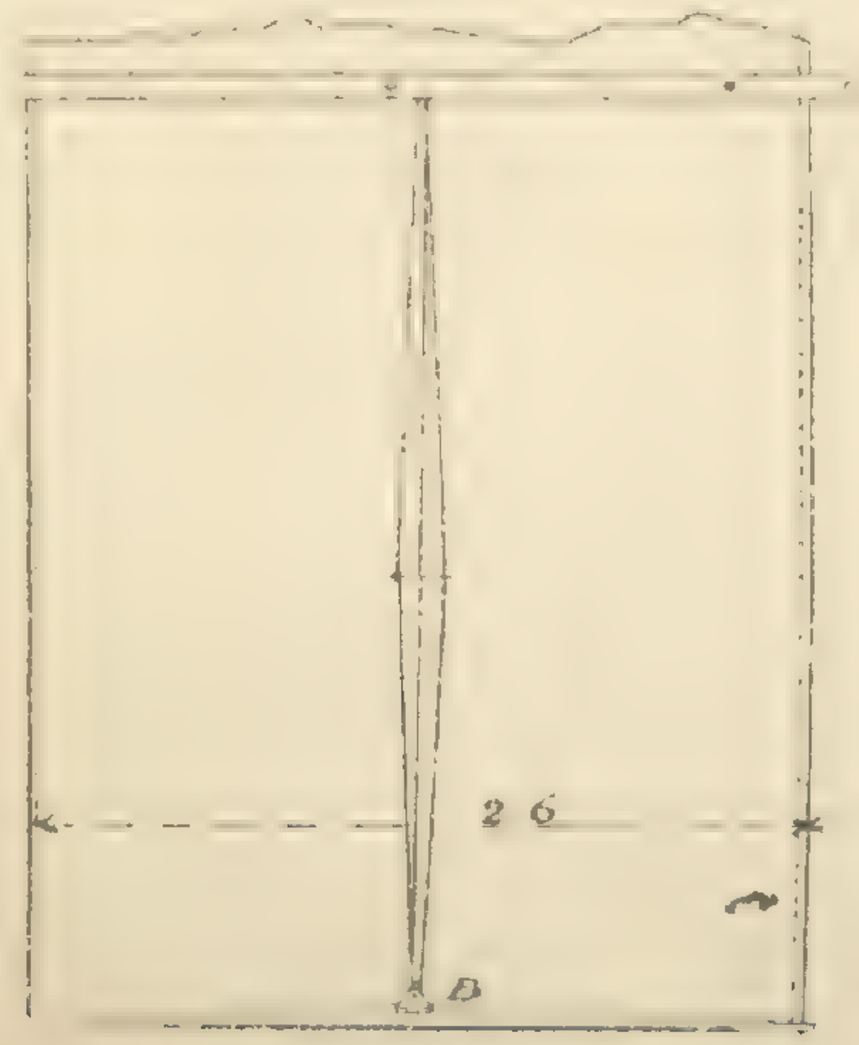
Horizontal and partly curved Surface		158	square feet
Nearly vertical Surface on the Sides		51¼	square feet
Length	(over the sails)	10 feet	1 inch.
Beam	at the middle deck)	11	6
Height	(between decks)	2	6
Length	(between the sails)	3	1

Weight of Main-frame	9 Pounds	0 oz.
" " Booms & Yards	9	8
" " Sails	5	0
20 Bending Sticks	1	3
Total Weight	24	11

Diagram. VII.

Journal Royal Society of N.S.W. Vol XXIX. 1895





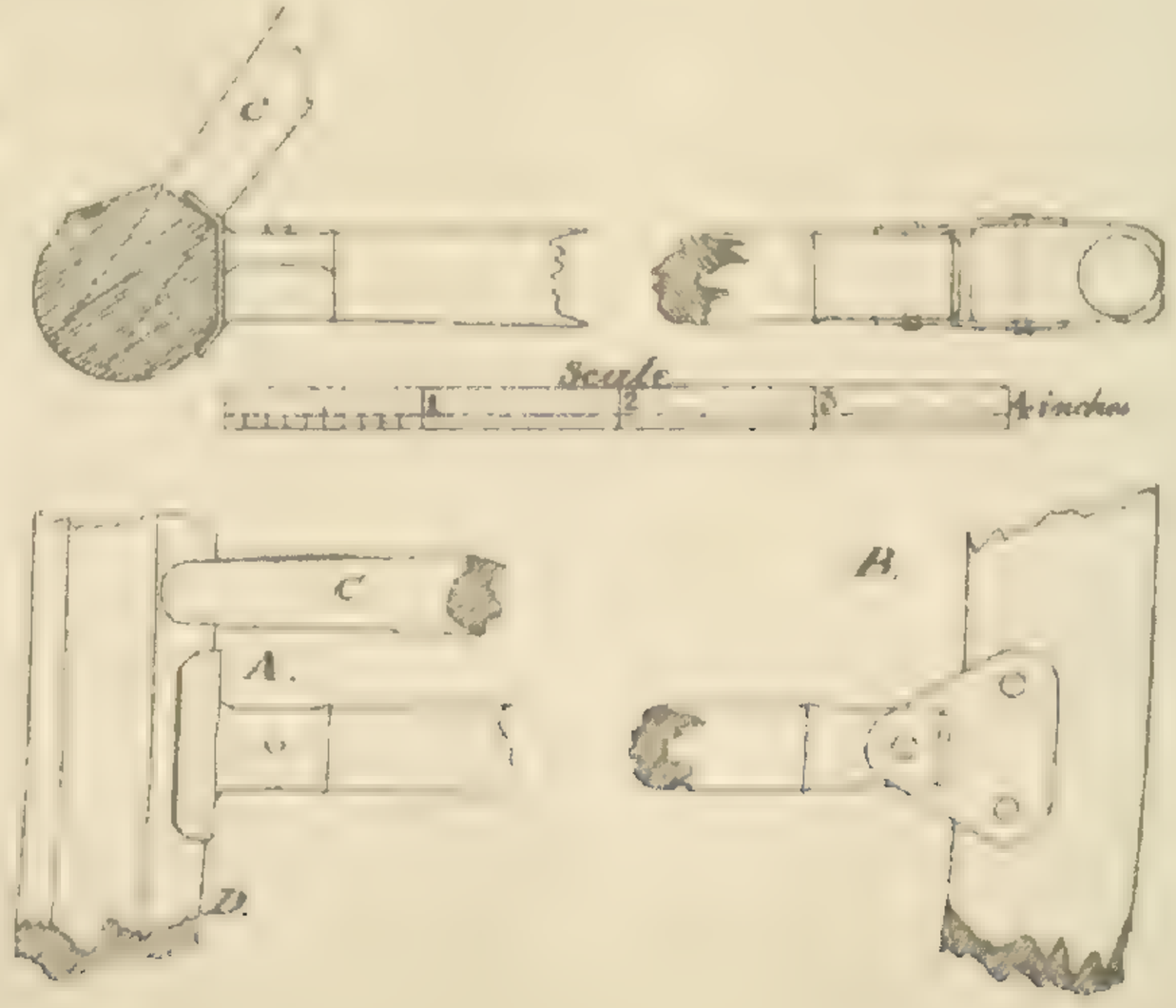
Cellular Kite.

65 square feet area.

9 pounds weight.

3'6"

Diagram VIII.



Dimensions.

Kite	Length of each cell		Breadth of each cell		Depth of each cell		Distance between the cells		Distance from the fastened end of the sewn cell to the point of attachment of the kite line		Weight of the kite		Area of the surface of the kite, including supporting surface.
	feet	ins	feet	ins	feet	ins	feet	ins	feet	ins	pounds	oz	Square feet
A	1	11	5	0	1	10½	2	1	1	7	5	7	38·5
B	1	11	5	0	1	10½	2	4	1	7	5	14	38·5
C	2	3	7	8½	1	10½	4	5	2	8	9	8	69·
D	2	6	6	6	2	3½	3	6	2	3	9	0	65
E	2	6	9	0	2	6	4	6	2	10	14	8	90

Diagram. IX.

Side View of Kites.

Weights of

The four kites Millwood

Lines & toggles over 3

Sling seat 2

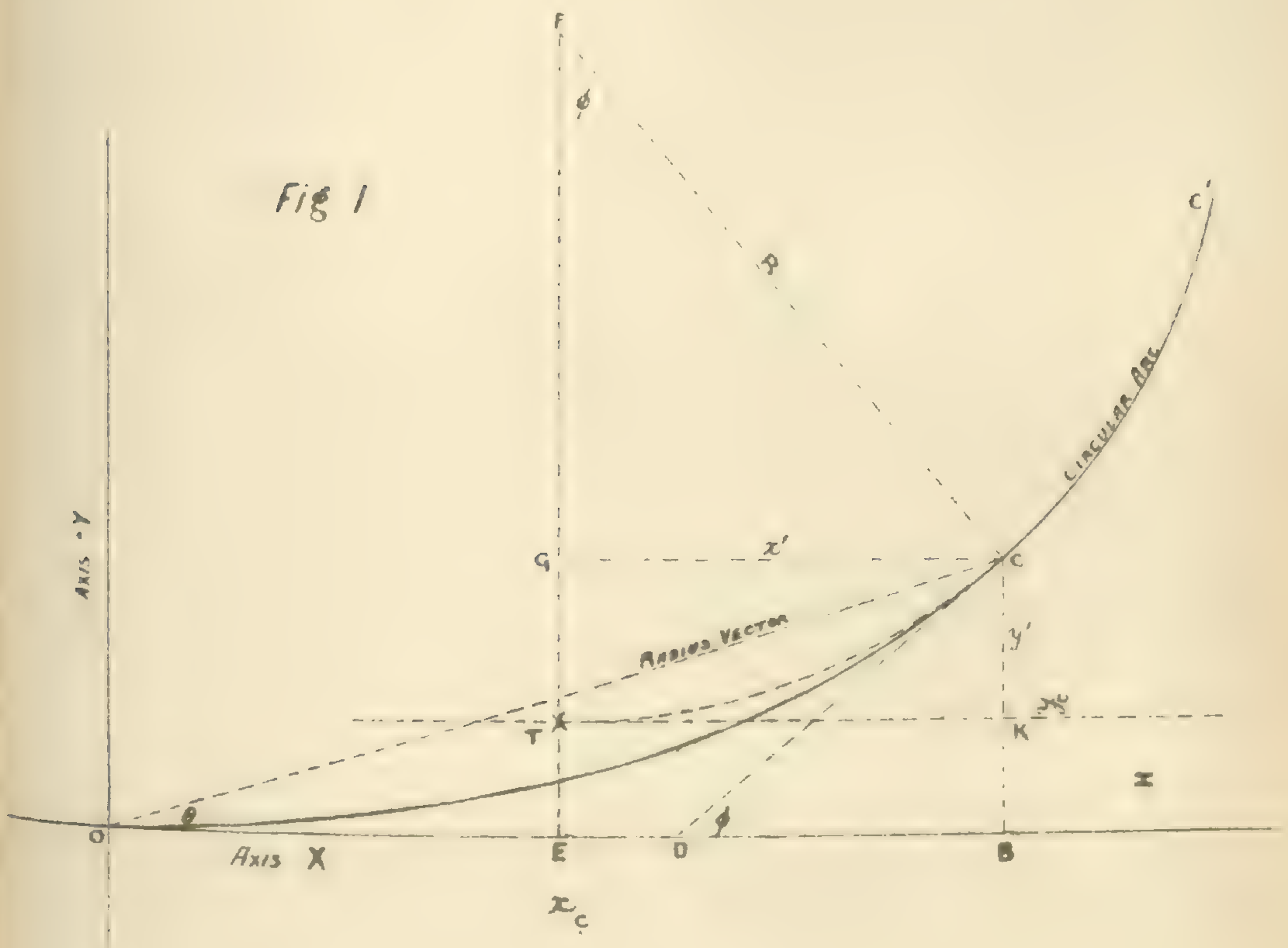
Anamometer &c. *Max 166lb* 16T

Total 20 cwt

Area of 232 sq feet

Velocity of wind at E 21 miles

Fig 1


F
φ
ρ
C'
CIRCULAR ARC
AXIS Y
G
x'
C
RADIUS VECTOR
y'
T
K
θ
O
AXIS X
E
D
B
x_c

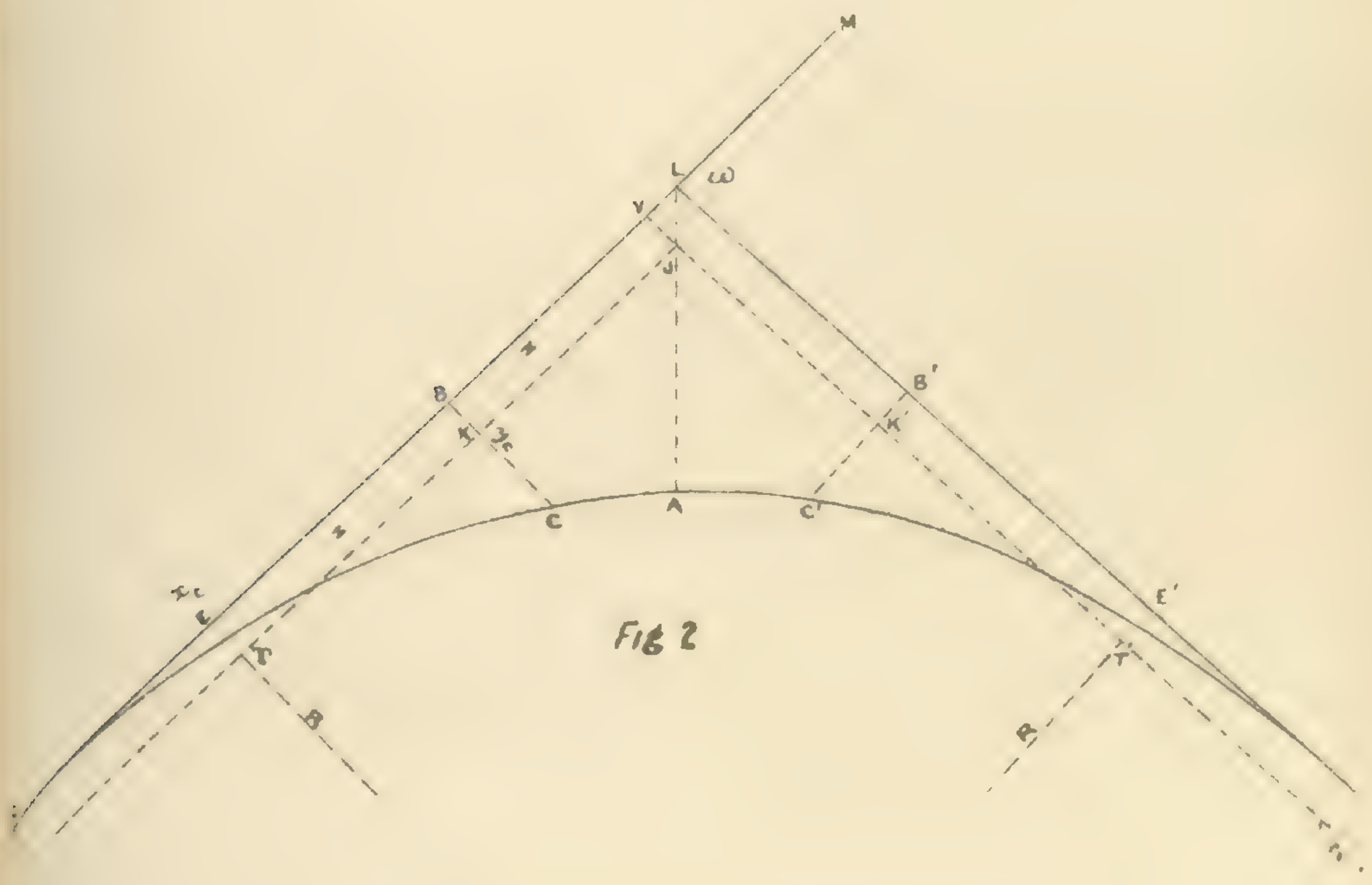

M
L
ω
V
B
B'
C
A
C'
E'

Fig 2

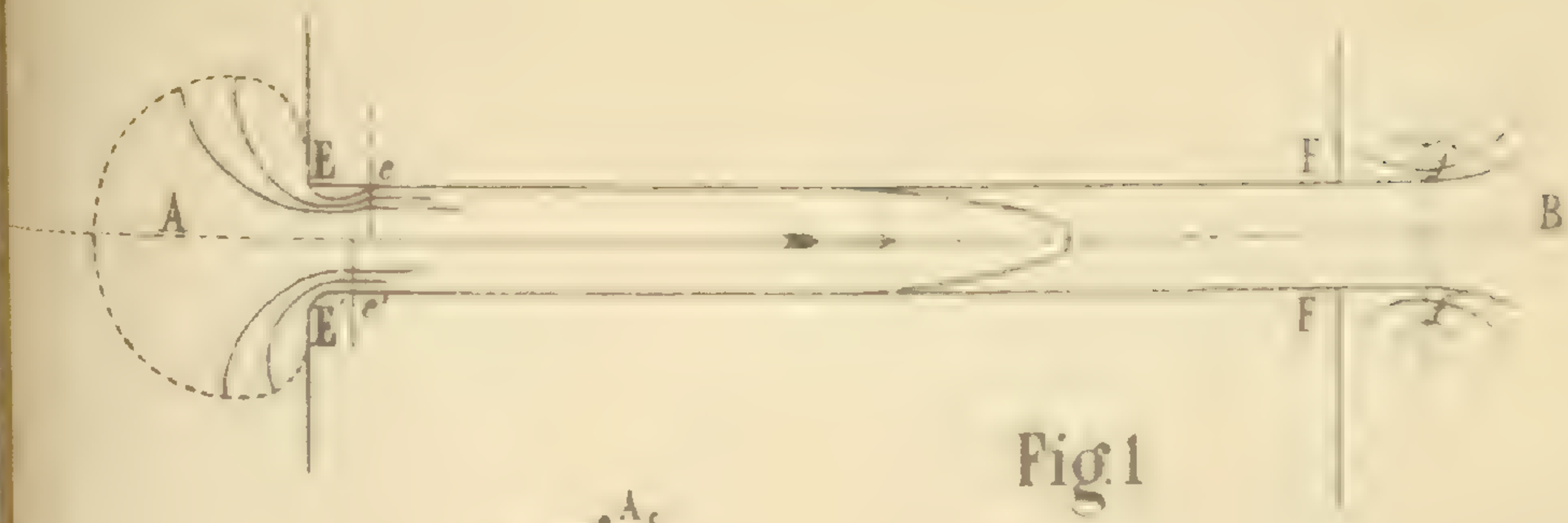


Fig. 1

Fig. 2

Fig. 3

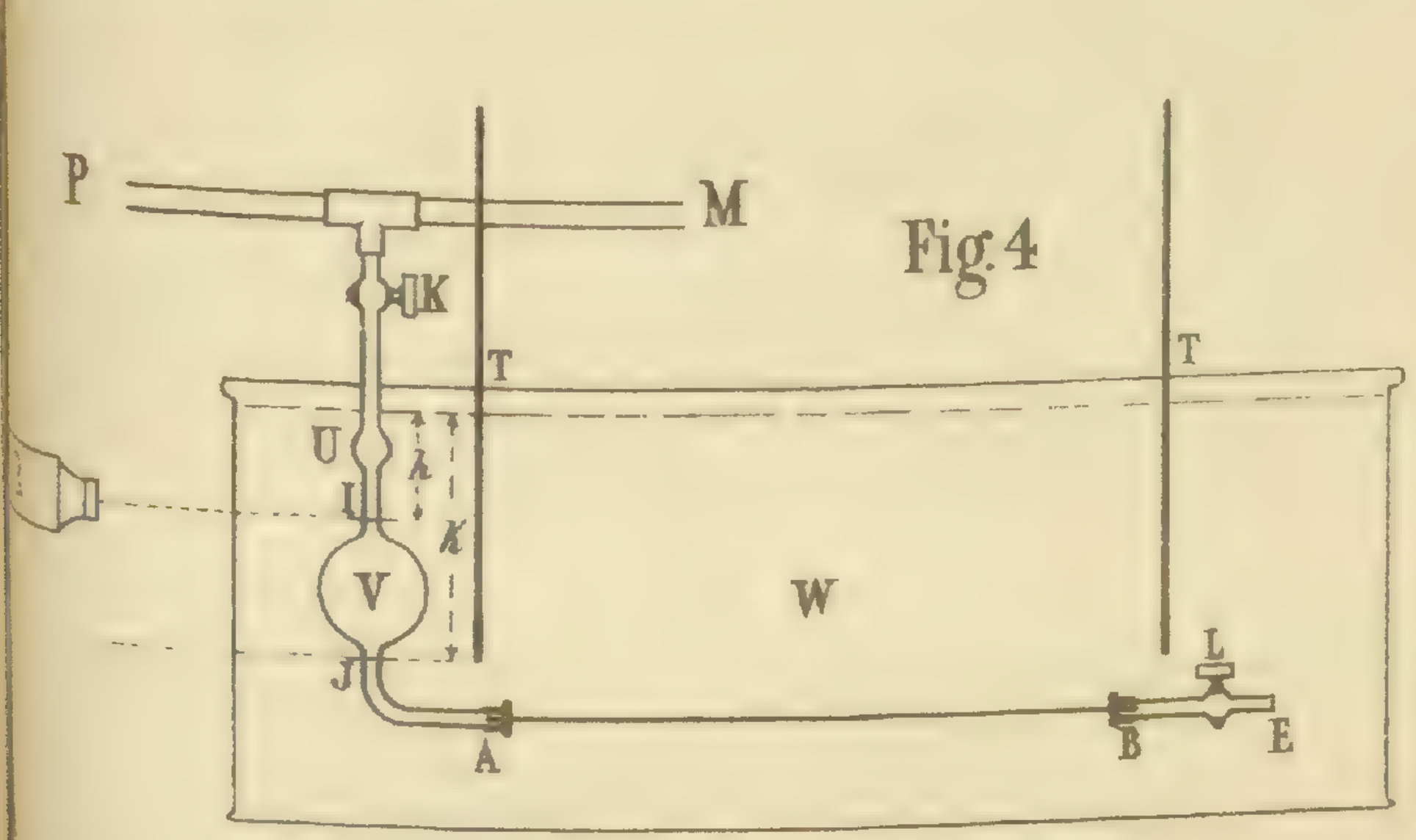


Fig. 4

G. H. Knibbs delt.

G. H. Knibbs on Viscosity.

20°
10°
0°
10°
20°
30°
40°
50°
60°
70°
Wake I
Johnston I
Gasper Rico
Eschscholtz I
Dawson
Radokala
Schans
Providence
Lydia
Oman I
Ailuk
New Year
Kaven
Mamau
MARSHALL I
Elmore
Pedder
Mulgrave I
Milli
Kyli
Bering
Hunter
Boston
Strong I.
Indiana R
Touching
Pitt
Charlotte
Hall
GILBERT I
Hopper
Howland
Baker I
Pleasant
Ocean
Sydenham
Drummond
Byron
Rotcher
Hurd
Phoenix I
Enderbury I
Arthur I
Phoenix
Gardner I
Sidney I.
St Augustine
Speiden
Netherland
Tracy
Ellice I
Ellice
Howe
Stewart
Malaita
Kennedy
Sta Cruz I
Cherry
Vanikoro
Tucopia
Sophia
Rotumah
D. of York I
D. of Clarence I
Danger I.
Samoa or Navigator I
Uea
Manua
Rose I
Banks I
Vanua Lava
Esp Santo
Aurora
Pentecost
Api
Sandwich
Erromango
New Hebrides
Huon I
Tanna
Aneiteum
Lifou
Mare
Walpol
Hunter
Conway
New Caledonia
I of Pines
FIJI I
Vanua Levu
Viti Levu
Kandavu
Matuku
Exploring I
Reid I
Ongea
Vatoa
Ono
Amagura
Vaveu
Hapai
Tongatabu
Pylstaart
Friendly I
Nuie
Beveridge
Palmerston
Minerva R
Norfolk I
Sunday I
Kermadec
Esperance
Howe I
3 Kings
North C
B of Islands
Hokianga R
Kaipara H
Manukau H
Kaohia H
Hauraki G
B of Plenty
East C
NEW ZEALAND
NORTH I
C Farewell
C Foulwind
Hokitika
Jackson B
Milford Sd
Charles Sd
SOUTH I
Tiwaru
Resolution I
C Providence
Solander
Stewart I
Foveaux Str
The Traps
Snares
Christchurch
Banks Pen
Chatham I
Antipodes I
Auckland I
Campbell I
Emerald I (D)
Pitcairn I
43
41
75
35
42
34
12
86
69
150° East Longitude 170°

An Admiralty Chart used

PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE,
SYDNEY, NEW SOUTH WALES.

SOUTHERN OCEAN
1895

By

H.C. RUSSELL
GOVERNMENT ASTRONOMER
SYDNEY

INDIAN OCEAN

ARABIAN SEA

BAY OF BENGAL

Enderby Land

King Land

Ice Barrier and High Land

Appearance of Land

East Longitude 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120°

20° 10° 0° 10° 20° 30° 40° 50° 60° 70°

Fig 1

Fig 2a

Fig 2b.

Fig 3

Fig 4

Fig 5.

Fig 6

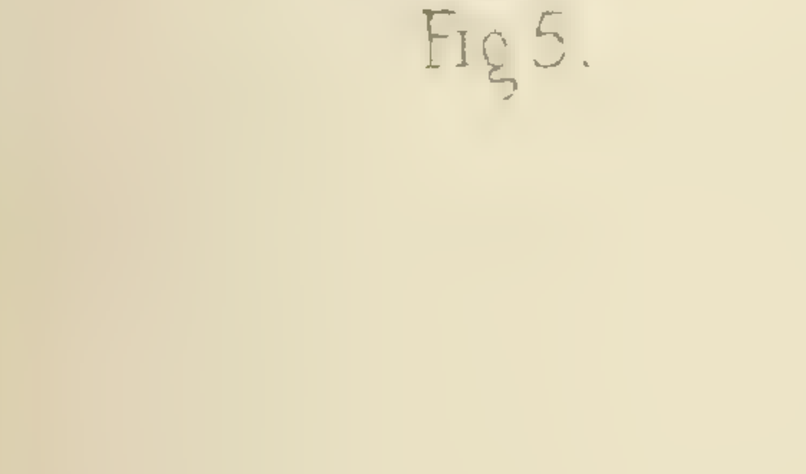


Fig 7

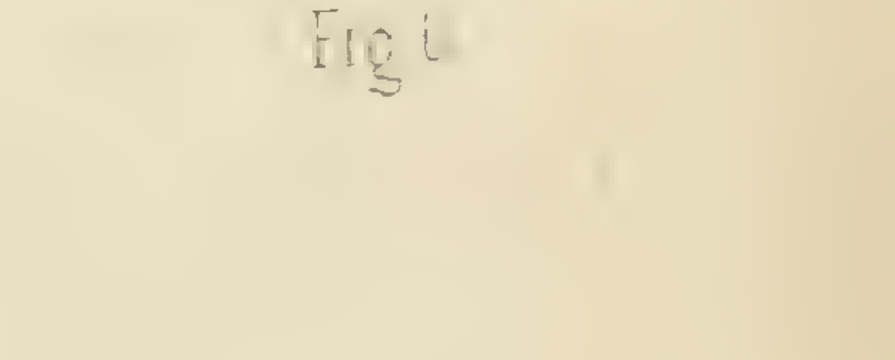


Fig 8.

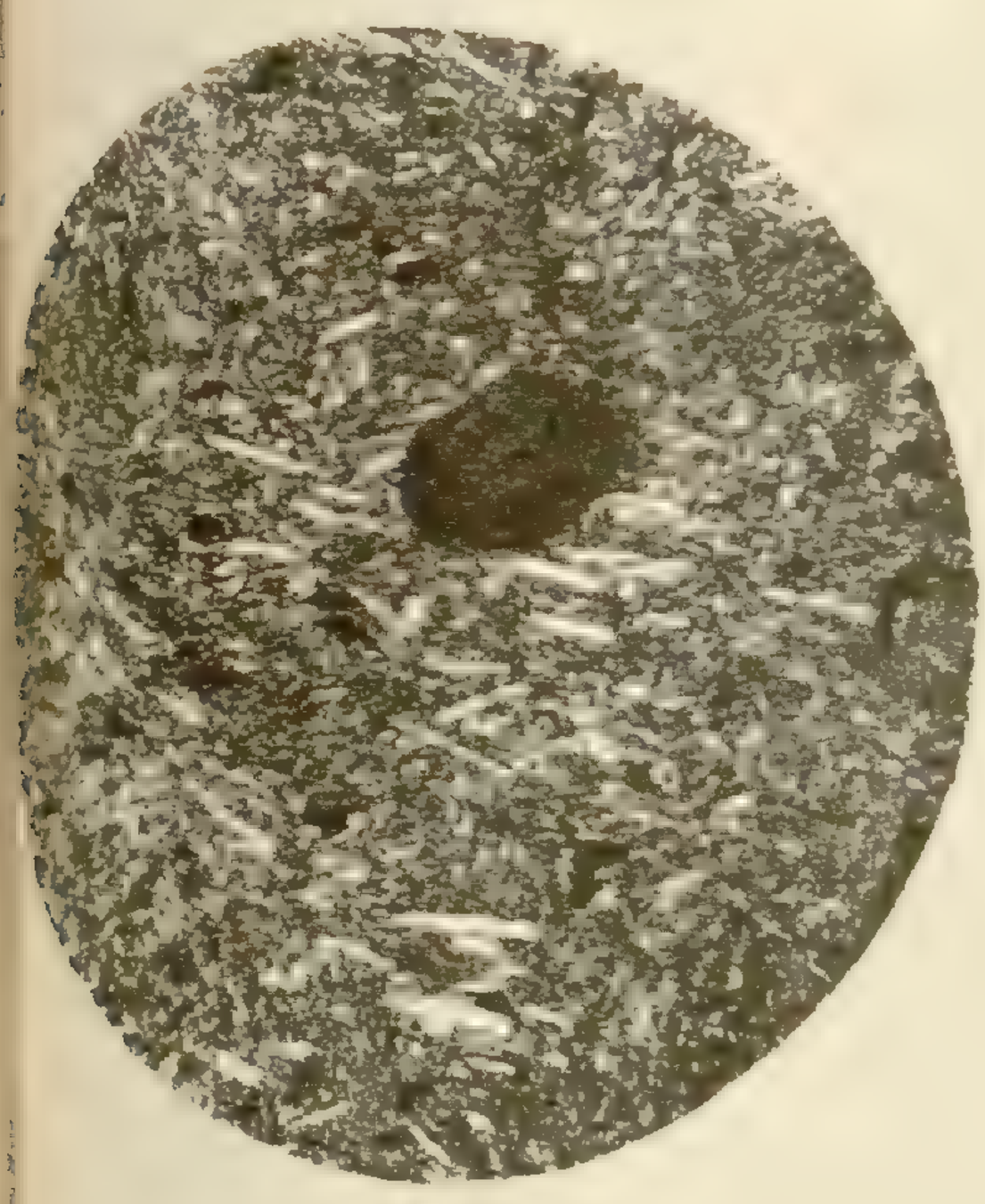


Fig 1

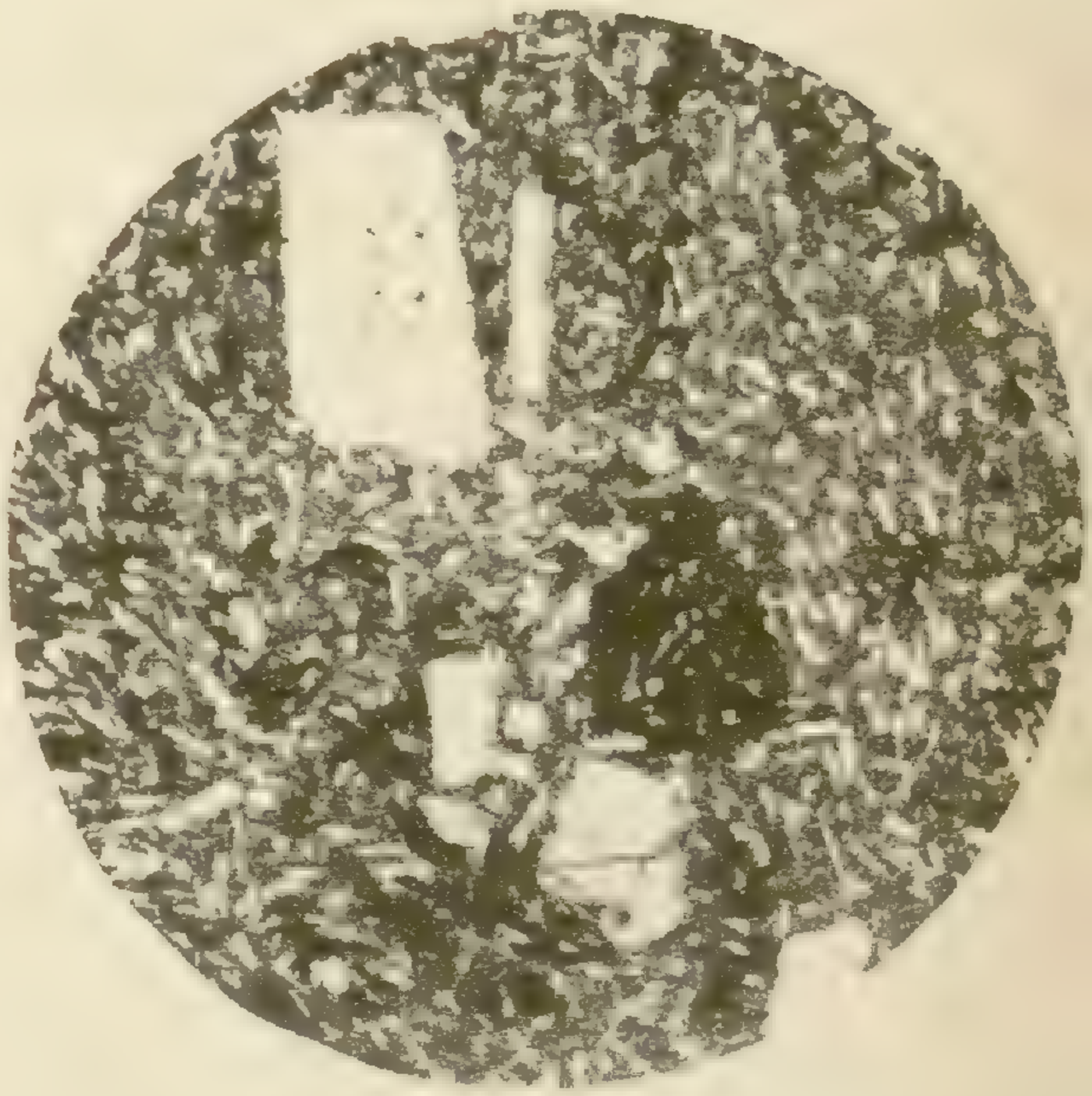


Fig 2

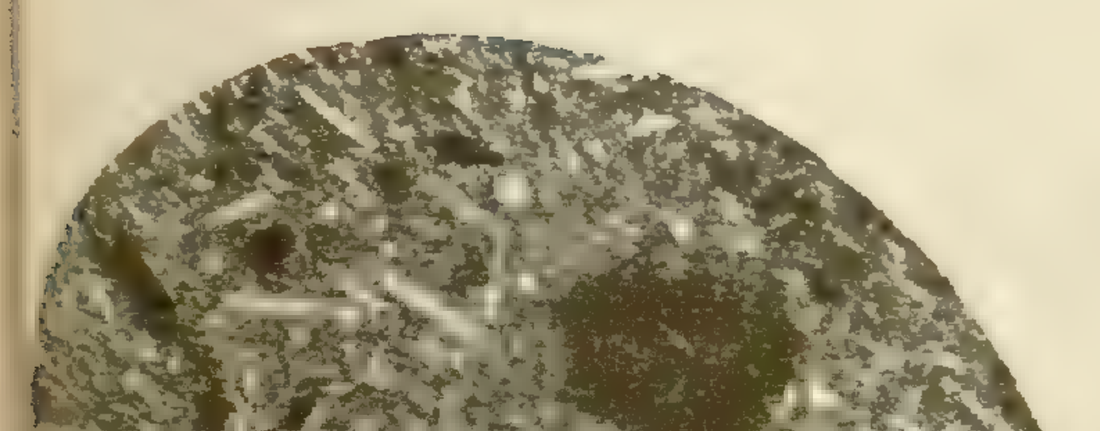


Fig 3

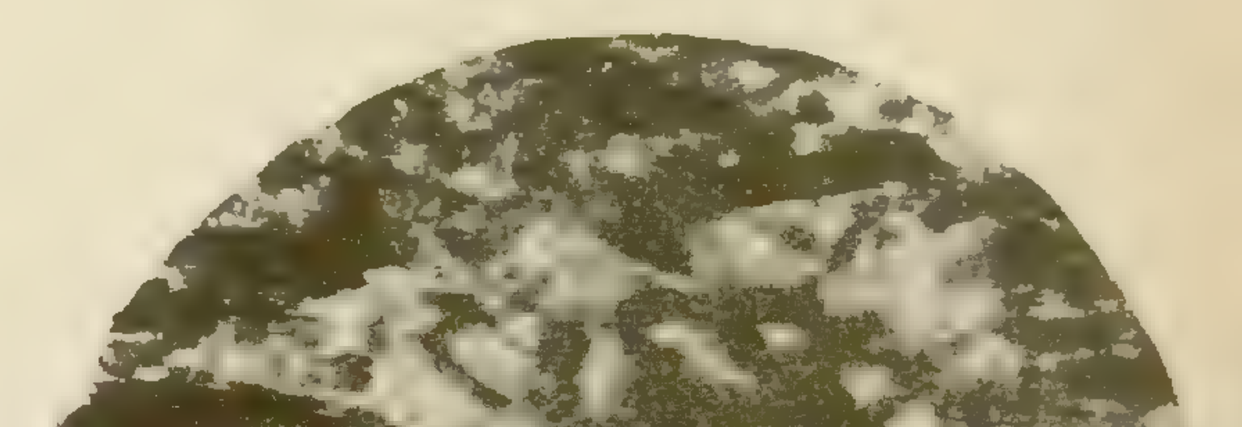


Fig 4

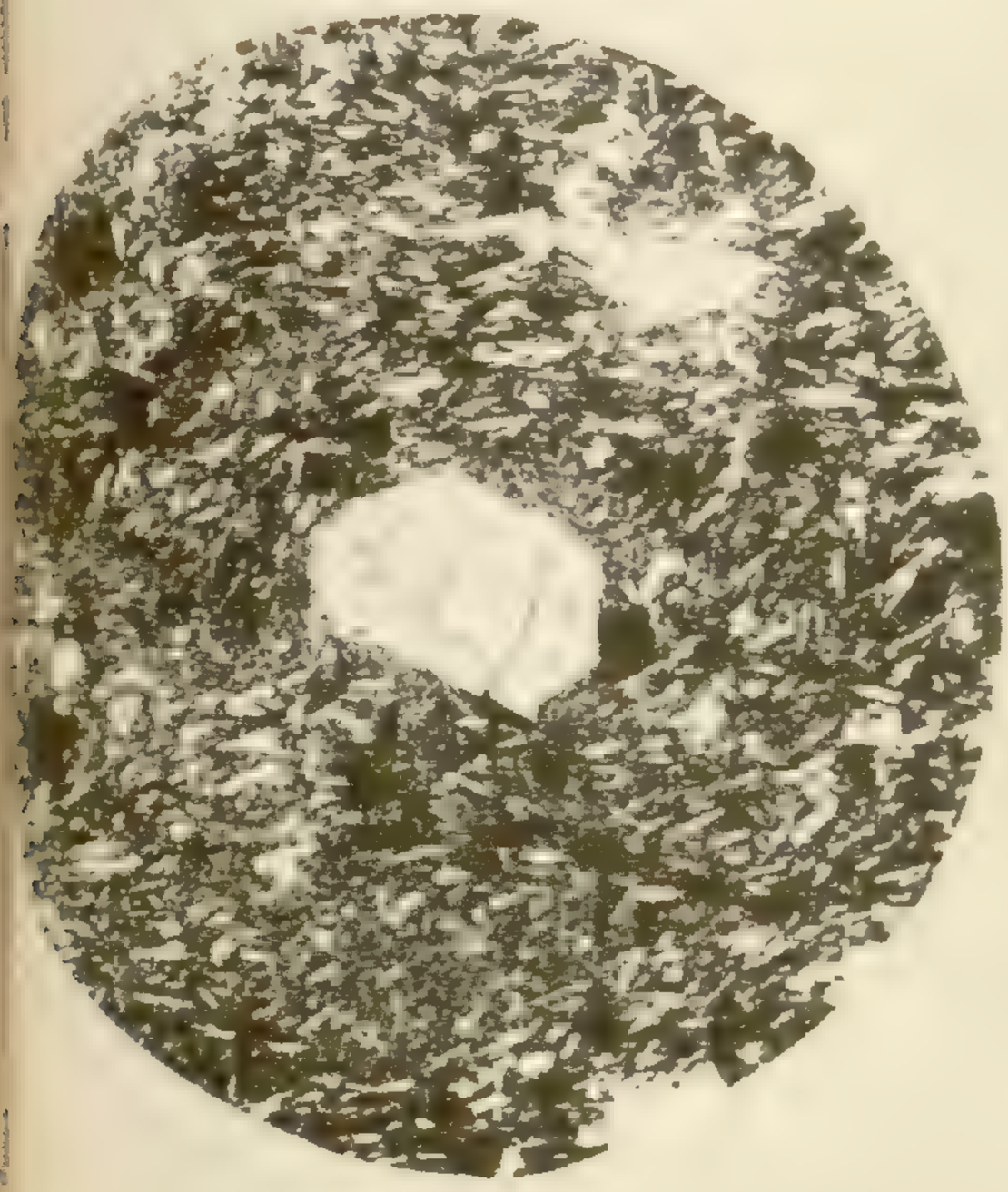


Fig 2.

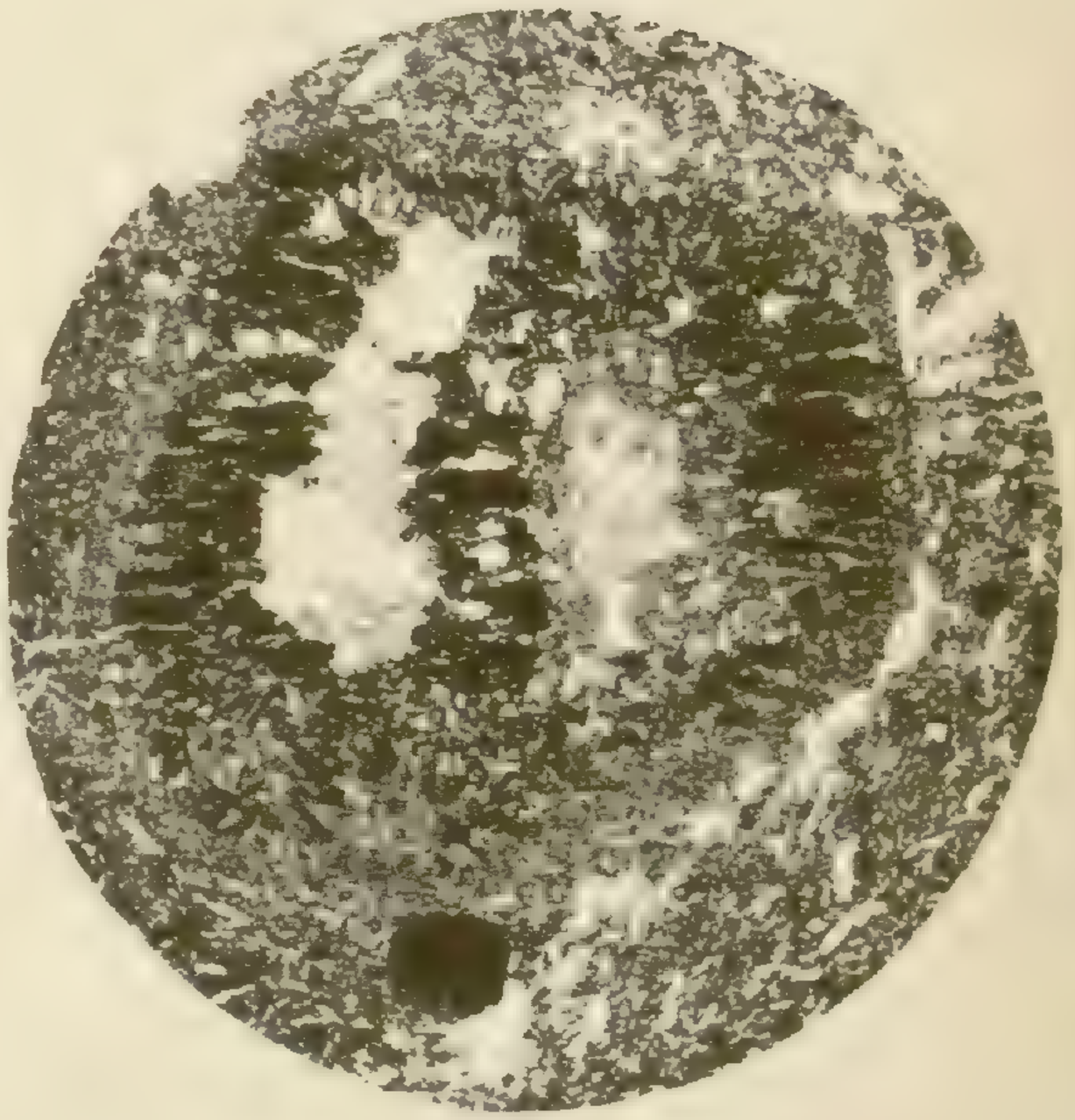
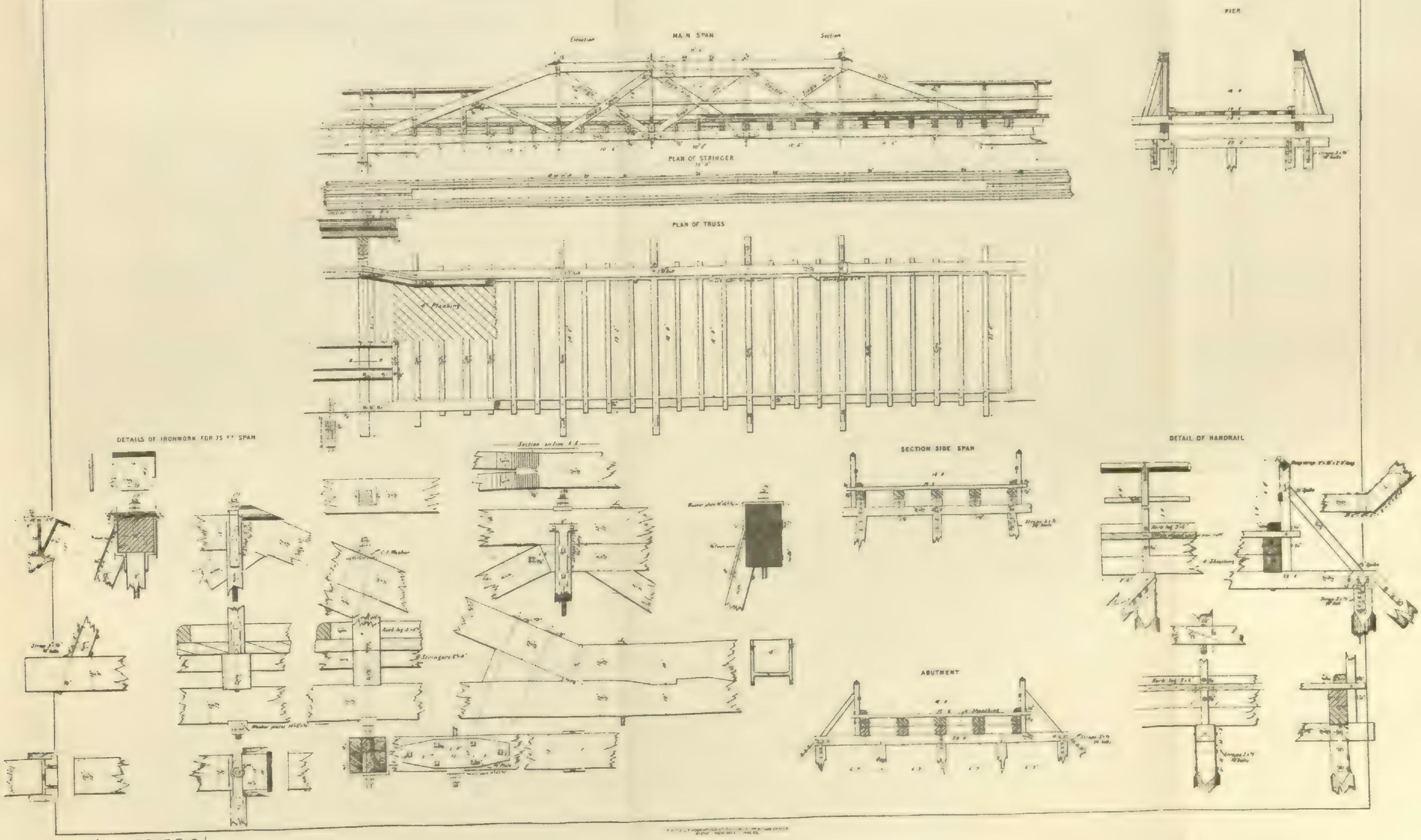


Fig 1.

Fig 3

Fig 4

PLATE I.



(9e 272-95-6)

PLATE 2.

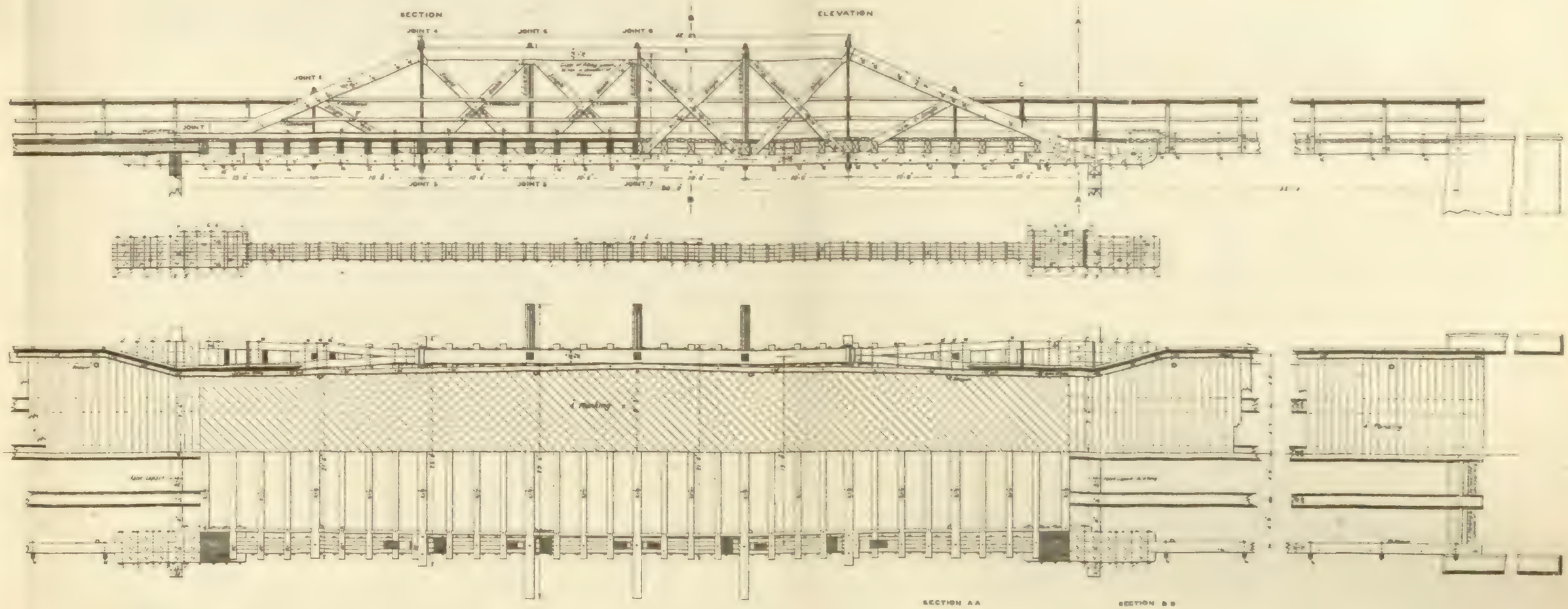
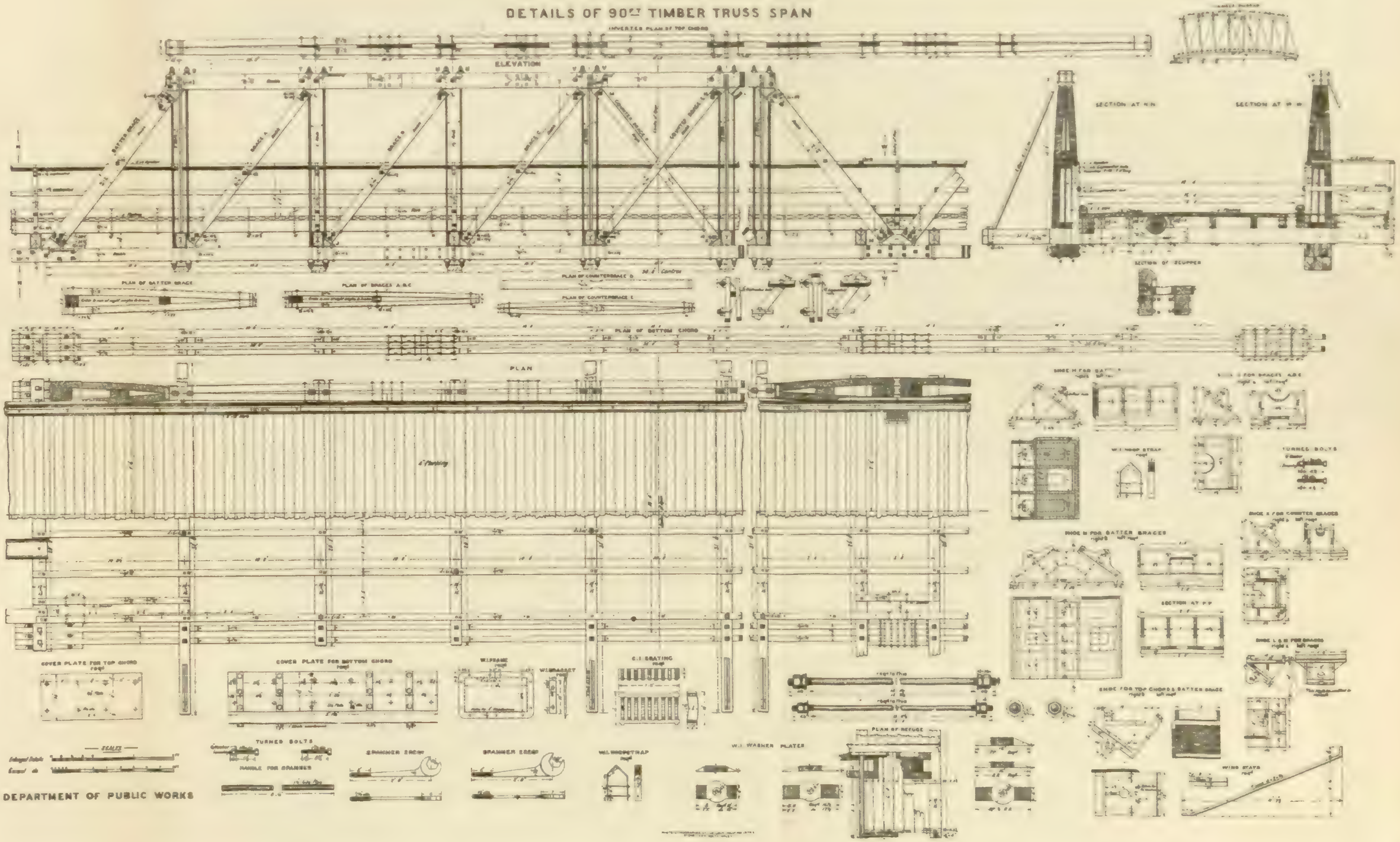

SECTION
ELEVATION
JOINT 4
JOINT 6
JOINT 8
JOINT 5
JOINT 7
JOINT 1
JOINT 2
JOINT 3
PLAN OF PRINCIPAL
PLAN of DISTANCE PIECE F
Scale 1½" to 1 foot
SCUPPERS
Truss Span
Approach Spans
SECTION A A
SECTION B B
SECTION E E
DETAIL OF POST AT C

PLATE 3.

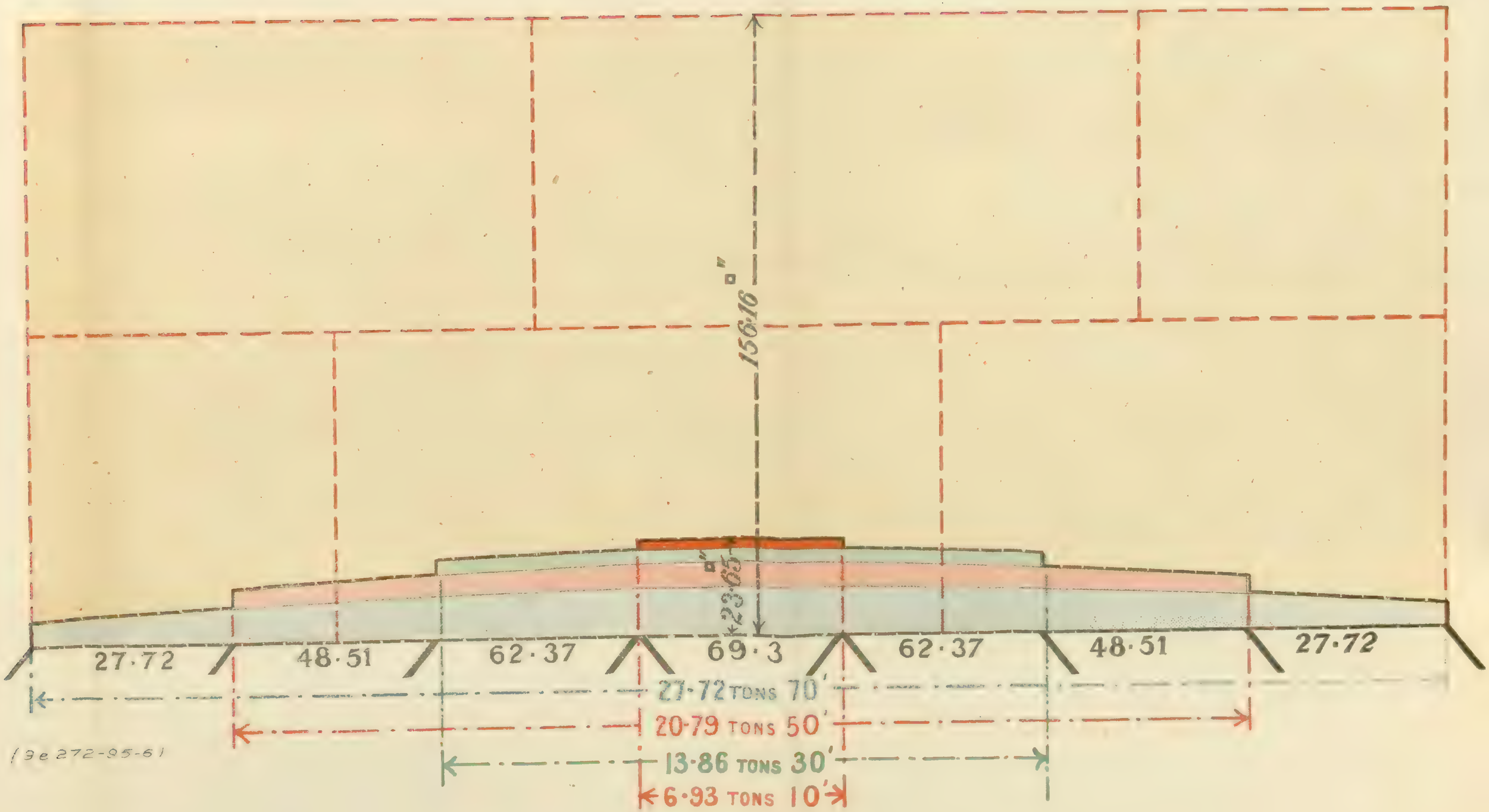
DETAILS OF 90FT TIMBER TRUSS SPAN



DEPARTMENT OF PUBLIC WORKS

(9e272-95-6)

PLATE 4.



(9e 272-95-61)

PLATE 5.

SCALE

FIG. 1.

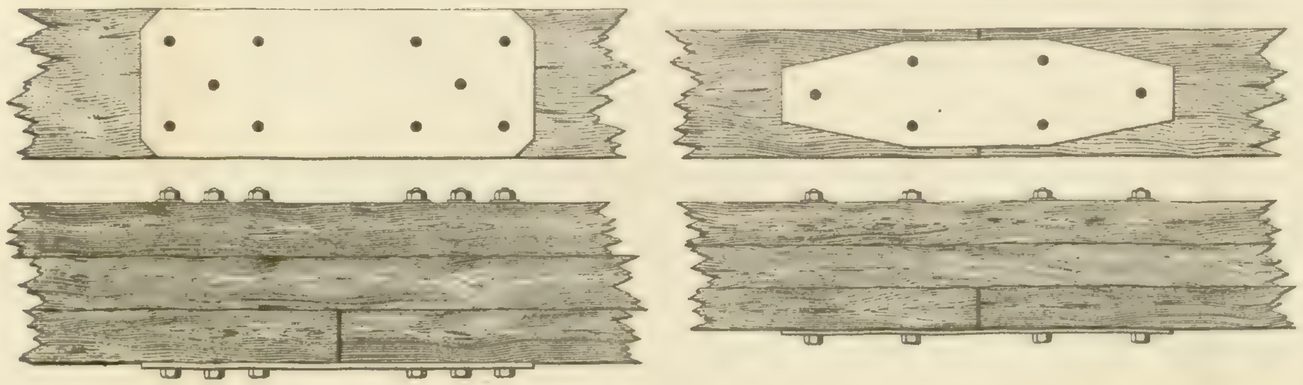


FIG. 3

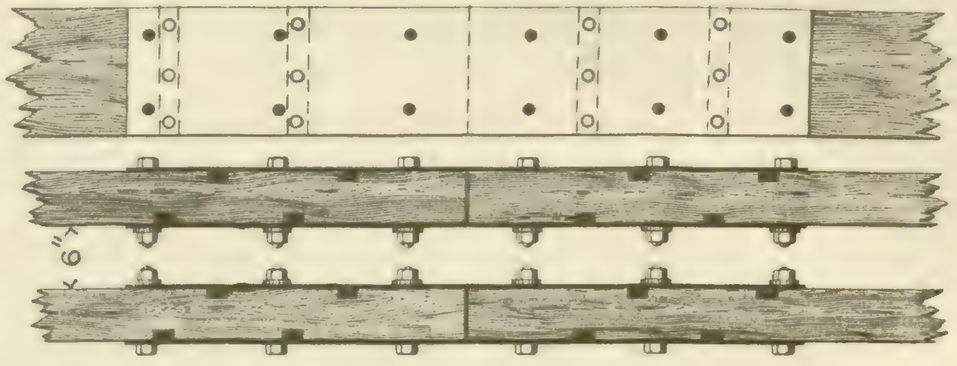


FIG. 2.

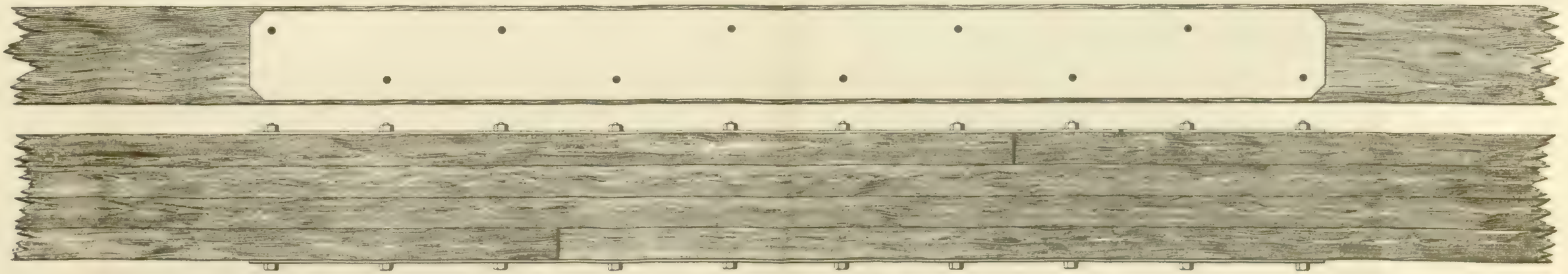


PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE,
SYDNEY, NEW SOUTH WALES.

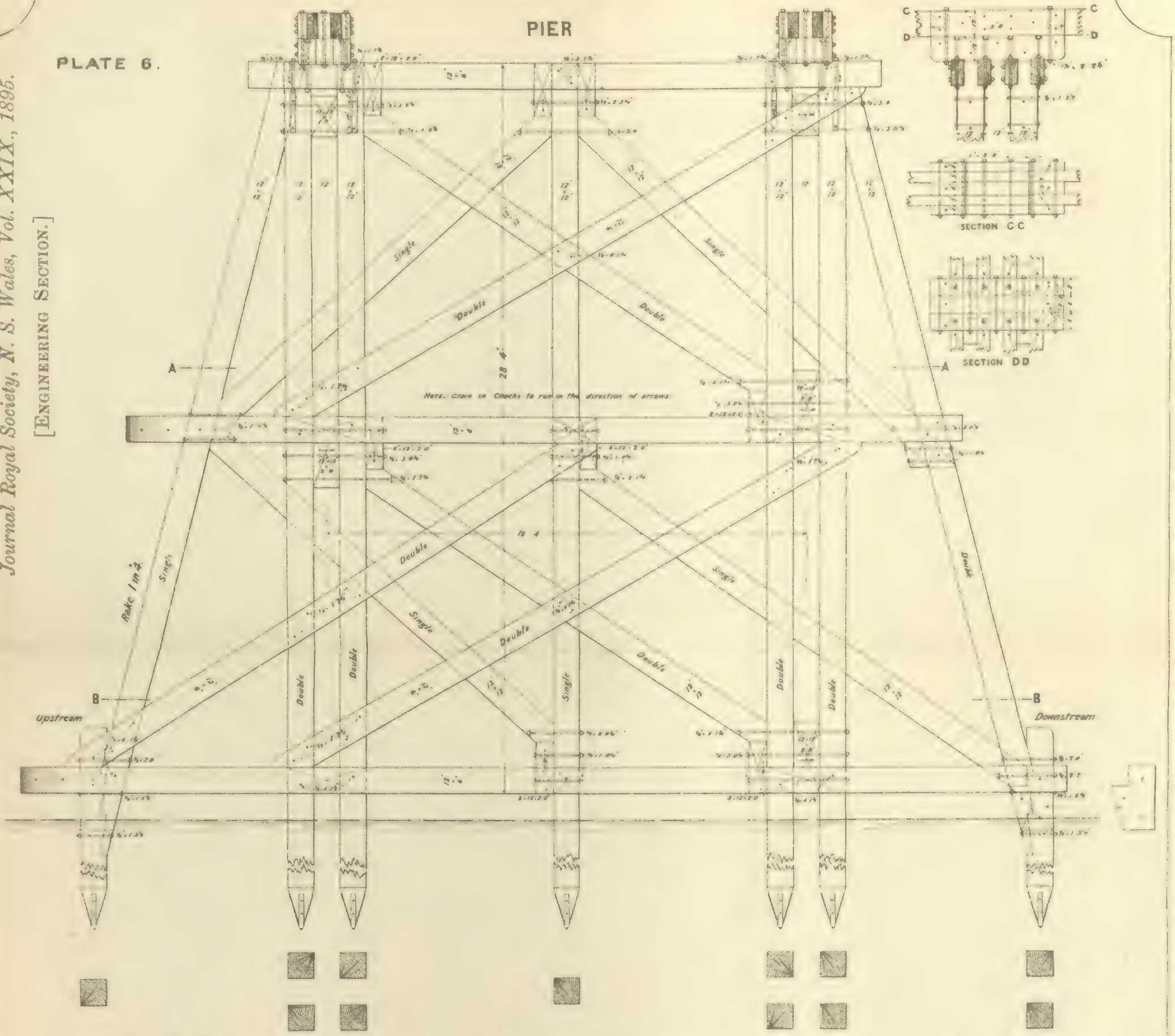
(94.272-95-6.)

Journal Royal Society, N. S. Wales, Vol. XXIX., 1895.

[ENGINEERING SECTION.]

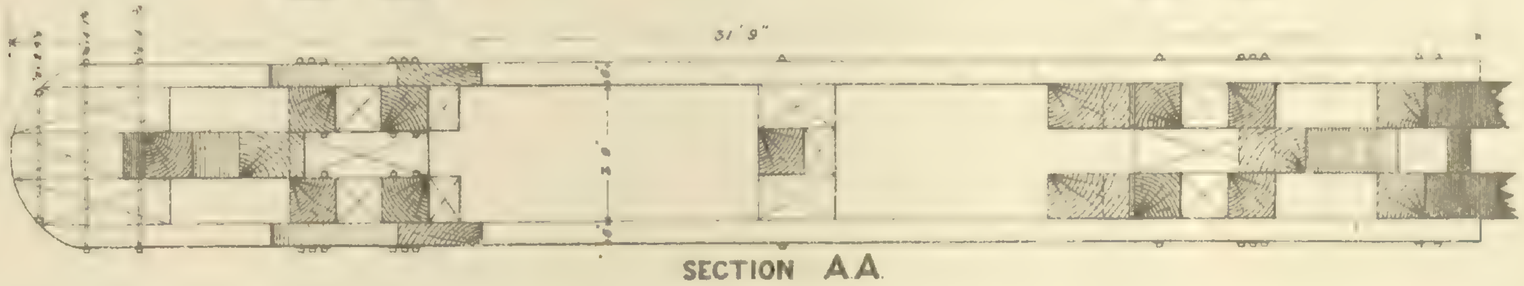
PLATE 6.

PIER

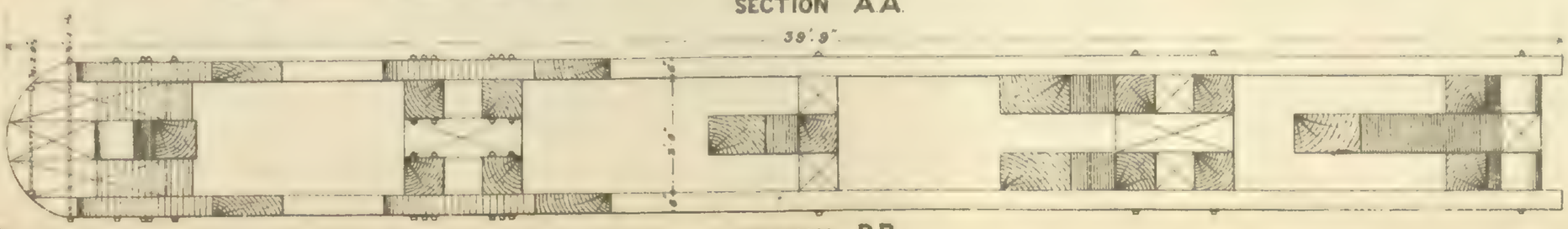


SECTION CC

SECTION DD



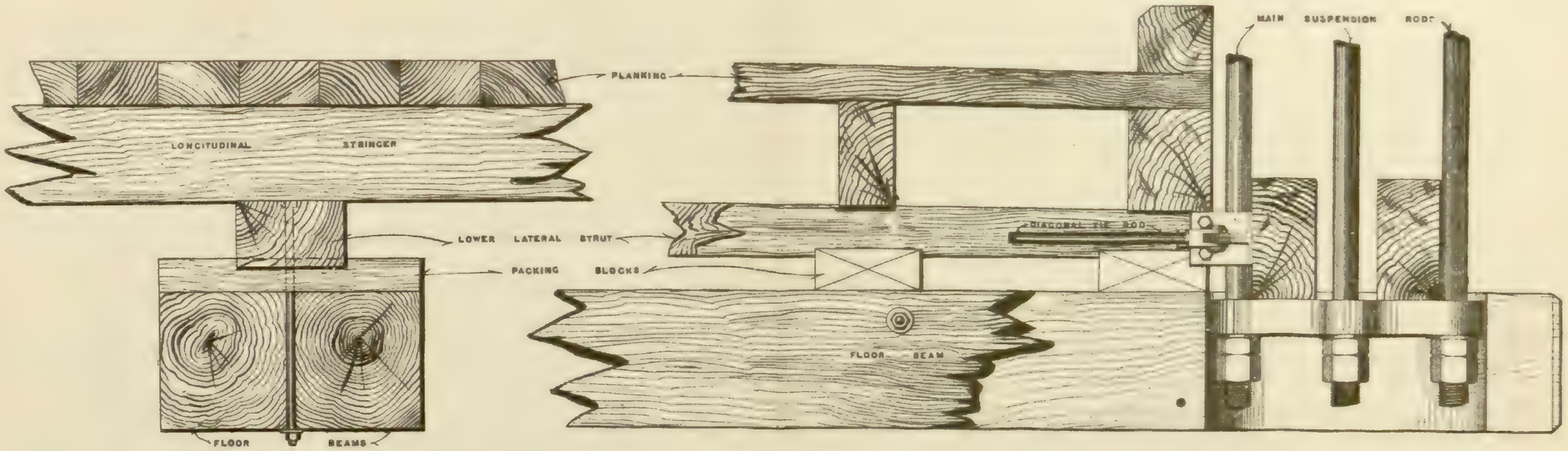
SECTION A.A.

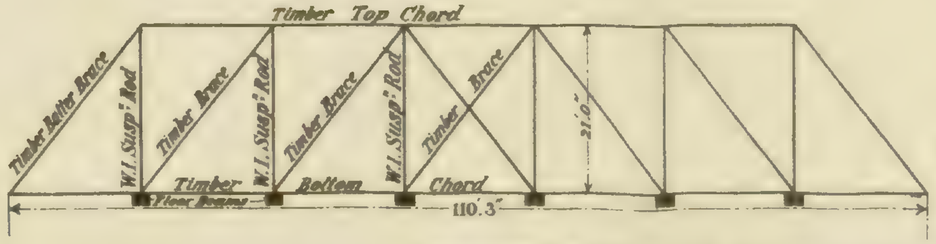


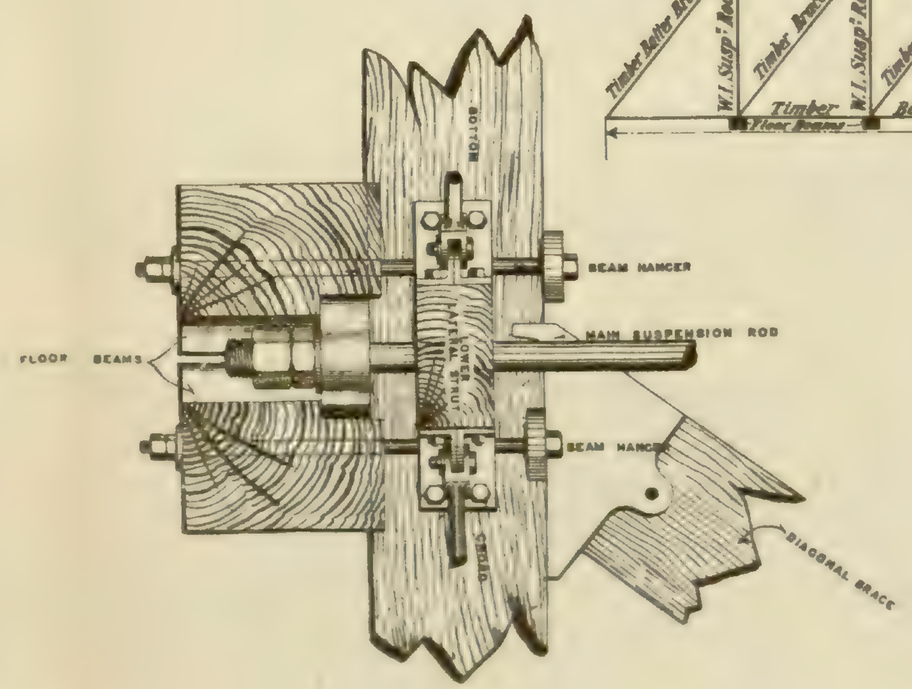
SECTION B.B.

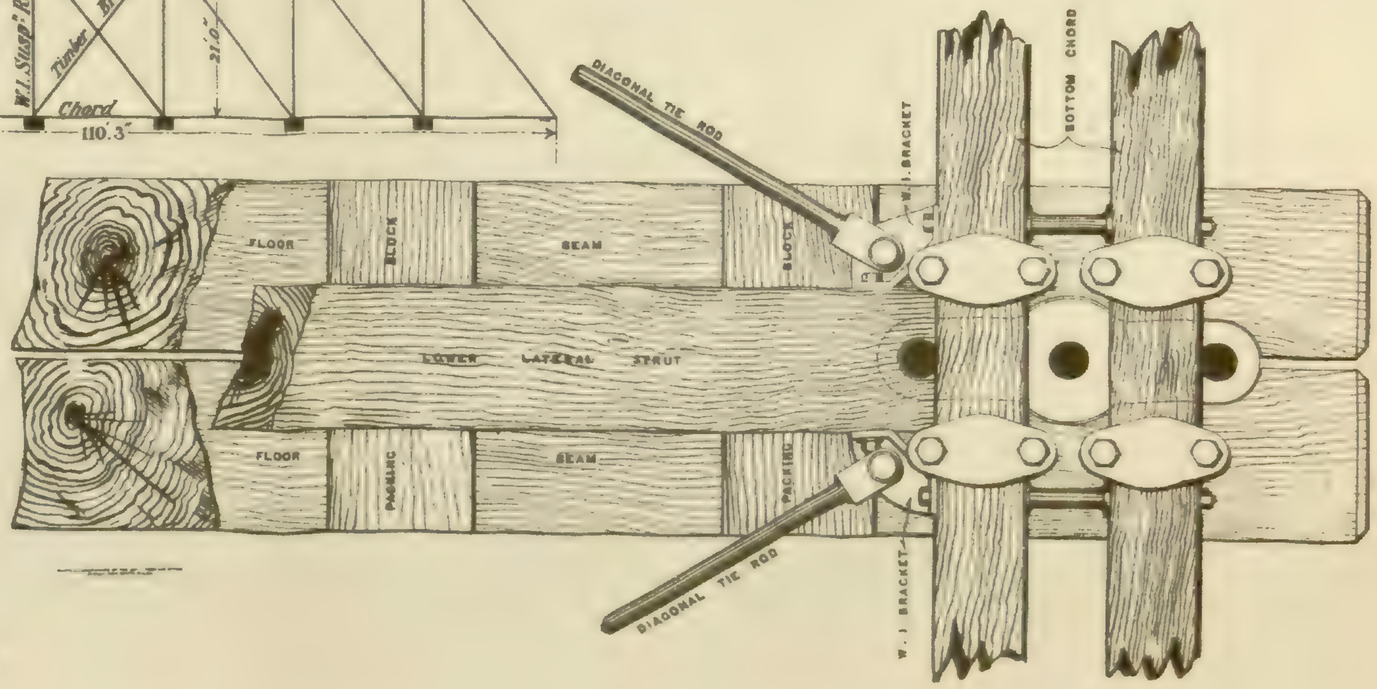
9e 272-95-6

PLATE 7.









(9e272-95-6)

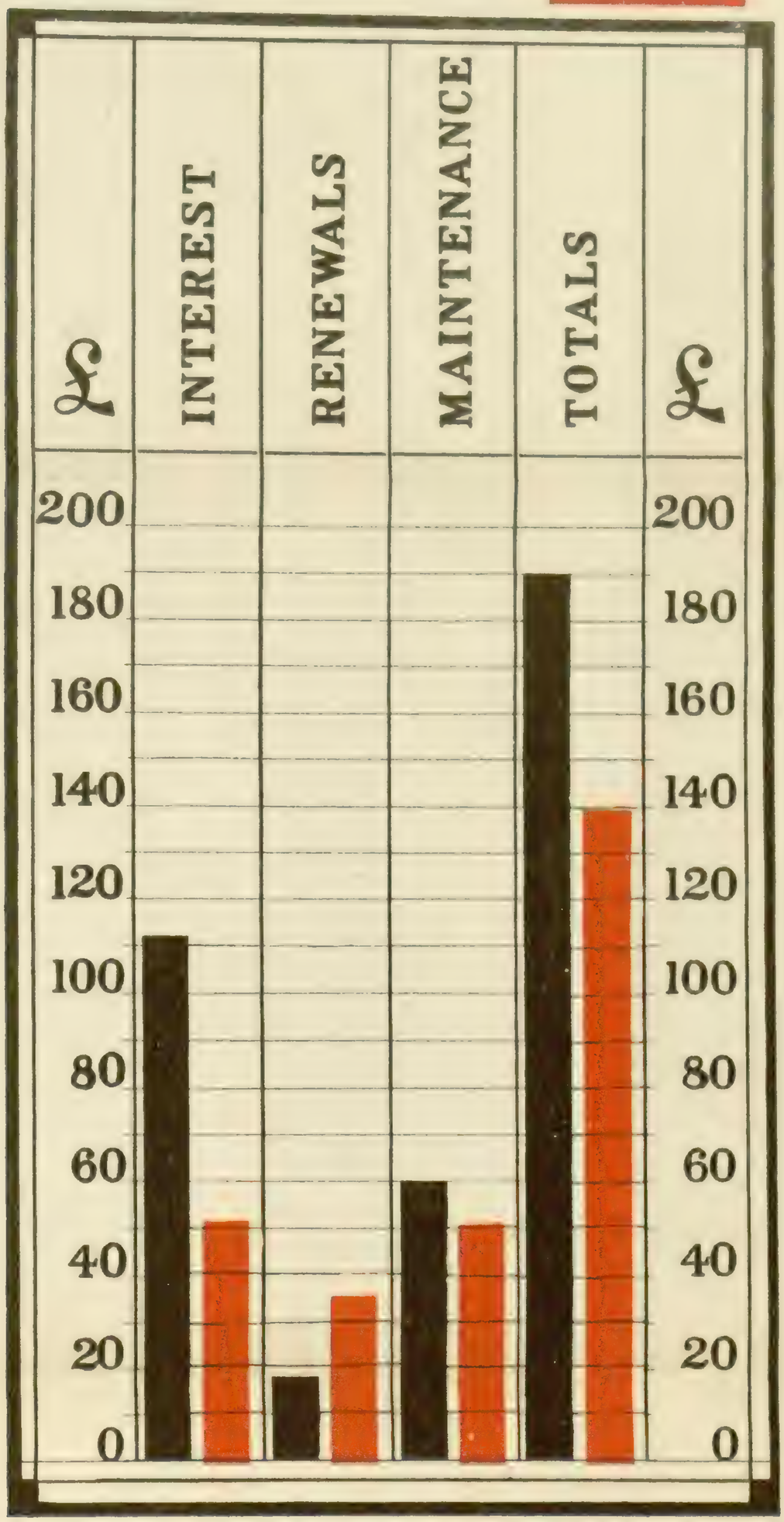
Journal Royal Society, N. S. Wales, Vol. XXIX., 1895.
[Engineering Section.]

PLATE 8.

DIAGRAM
OF
ANNUAL CHARGES

IRON BRIDGE SHOWN THUS

TIMBER BRIDGE SHOWN THUS



9e 272-95-6

A

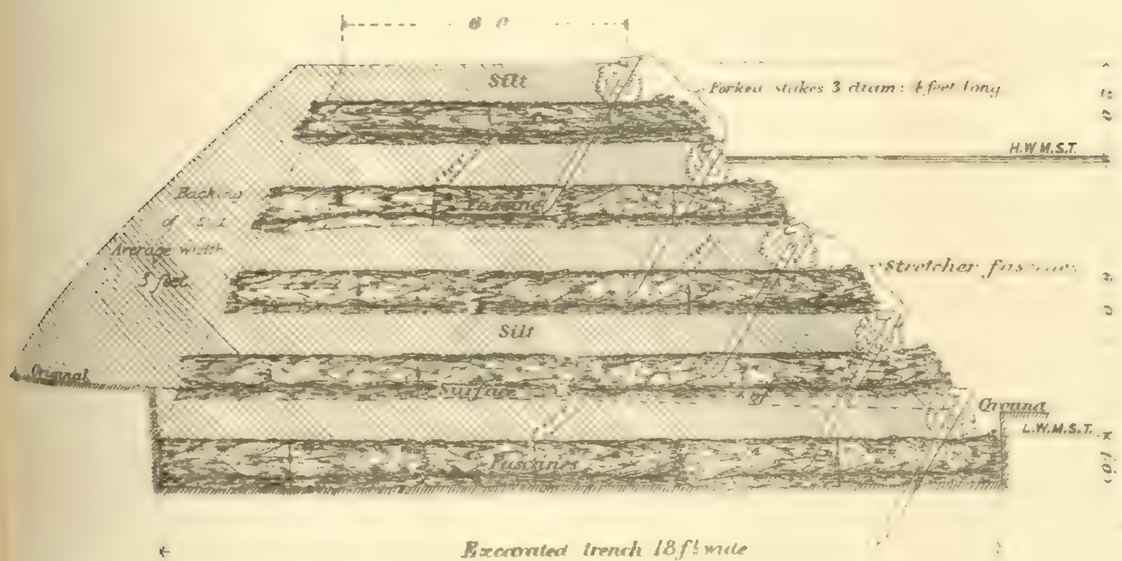
FASCINE WORK

PLATE 9.

CROSS SECTION OF ORDINARY DYKE

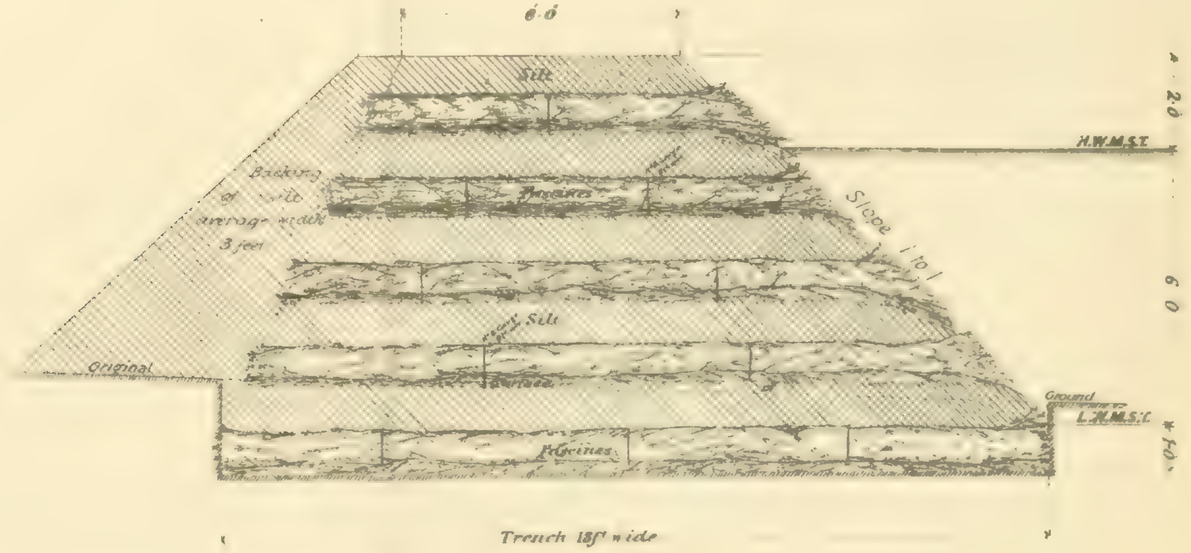
WITH STRETCHER FASCINE TO EACH SILT LAYER

Scale ½" = 1 foot



CROSS SECTION OF ORDINARY DYKE

Scale ½" = 1 foot



CROSS SECTION OF LONG COVE CANAL

AFTER SUBSIDENCE

Scale 20ft. = 1in

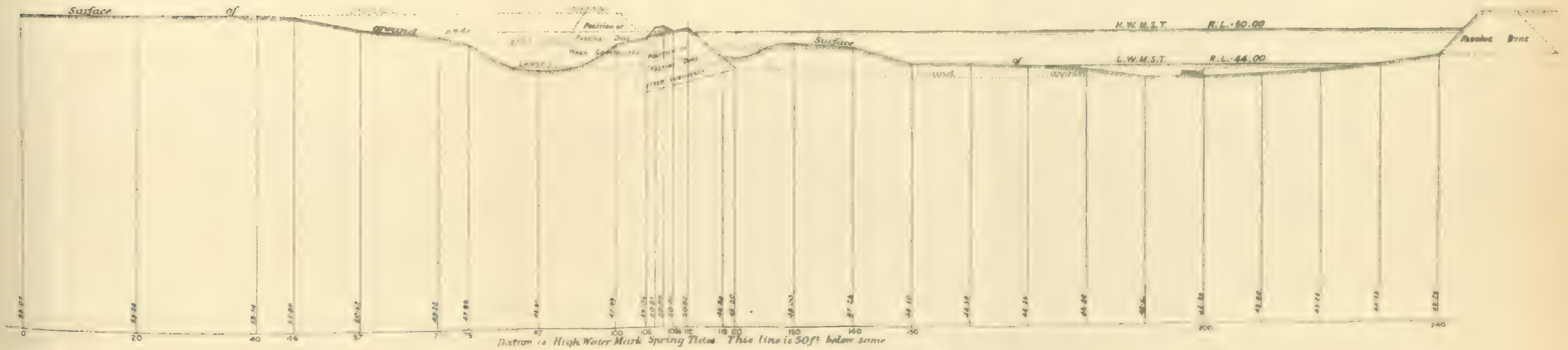
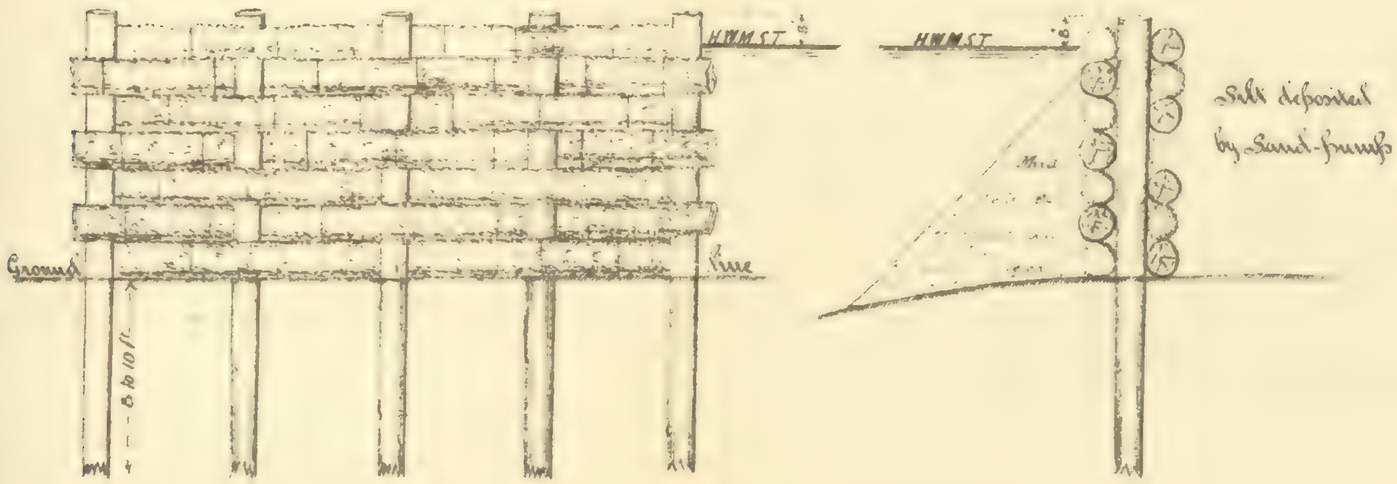


PLATE 10.

Fascine Wall

Scale 2 ins to one foot

B



Detail of Hinge etc.

Scale 2 ins = 1 foot

Great Marlow Levee

Showing type of boxdrain

Scale ½ ins = 1 Foot

Great Marlow Levee

Type of Bank used

Scale ½ ins = 1 Foot

TIMBER BRIDGE CONSTRUCTION IN NEW SOUTH WALES.

By Percy Allan, Assoc. M. Inst. C.E.

[With Plates 1 - 8.]

[*Read before the Engineering Section of the Royal Society of N. S. Wales, September 18, 1895.*]

The necessity for the economical designing of timber bridges in the Colony of New South Wales, may be gauged from the fact, that in the last ten years some 680 timber structures have been erected at a cost of £634,000, so that any economy in a type design means a very large saving in the annual expenditure of the Colony.

For many years *Plate* 1, was the type of truss for 65 feet, 75 feet, 90 feet, and 100 feet spans. The defects in this design may be briefly summarised—weakness in suspension rods, no means of taking up slackness in braces, caused by shrinkage of timbers, and tendency of top chord to incline inwards owing to want of lateral stiffness.

Although this type of truss has for many years carried the traffic without accident, yet in view of the increase in settlement and the greater risk of the structures being subjected to heavier loads, it was thought desirable in 1886 to adopt the design shown in *Plate* 2 for 65 feet, 75 feet, and 90 feet spans.

These structures were designed for a distributed live load of 84 lbs. per square foot of roadway and a traction engine weighing 16 tons, on a 10′ 4″ wheel base having $9\frac{1}{2}$ tons on the leading wheels.

The improvements in these trusses are the increased sectional area of suspension rods, the providing of means of taking up slackness in braces, increased lateral stiffness imparted to truss

by splaying principals, the introduction of iron in lieu of timber side braces, the more general use of sawn timber free from heart, and the more effective splicing of chord.

In 1893 to replace the 1886 type of truss bridges, Mr. Hickson, M.I.C.E., Engineer-in-Chief for Public Works for New South Wales, approved of the author's designs for new standard type of truss bridges for 70 feet and 90 feet spans, *Plate 3*. The 90 feet span is designed for a traction engine of 16 tons and a distributed live load of 18·8 cwts. per foot run, or $7\frac{1}{2}$ cwts. per lineal foot more than for the 90 feet truss bridge previously in use.

The truss is divided into nine panels of 10 feet with a depth of 13 feet measured between centres of triangulations, and carries a 15 feet carriageway and two 5 feet footways.

The timber generally employed is tallowwood for the planking and ironbark for the stringers, floor beams and trusses, the timber in trusses being cut free of heart; but in many districts the local timber, with a somewhat shorter life could be used for the planking and stringers.

The flat decks in the old type of bridges, resulted in water lying in pools on the surface of the planks, more especially in the centre of the roadway, where the wear is greatest; 3 inch scupper pipes along kerb line, even if not choked up, are therefore of little service.

To provide against this a camber of $1\frac{1}{2}$ inches in cross section of deck is provided in the new type of bridge, permitting of the quick escape of water through the large gratings at ends of spans.

Unlike previous designs, 4 inch transverse planking spiked to longitudinal stringers has been adopted, thus permitting of shorter lengths being obtained at a cheaper rate and of their being replaced with less trouble than diagonal planking.

Longitudinal stringers varying from $10\frac{3}{4}$" by 5" to 9" by 6" (to give camber in deck), pitched 3 feet apart, are bolted to the floor beams, in lieu of the intermediate floor beams used in all previous designs, effecting a saving in cost, and permitting of the concen-

trating of the loads at the apices; thereby relieving the bottom chords of secondary stress.

In all the old types of trusses, the suspension rods passed through the floor beams, and as the braces were also butted against the floor beams, the renewal of these timbers was rendered practically out of the question.

In the later design, *Plate 3*, the floor beams 15″ by 12″ spaced 10 feet apart are placed between the suspension rods, admitting of easy renewal, and at the same time saving the expense of boring large holes through floor beams for the passage of suspension rods.

With a view to renewals, the horizontal thrust from the braces is taken up by means of castings, having lugs 1½″ deep let into the chords, and where two lugs are necessary it will be noticed that the deeper lug is at the back of the casting, so as to distribute the thrust over a larger area and reduce the risk of failure by shearing between the lugs.

The advantage in using castings in lieu of a number of timbers bolted together to form butting blocks for the braces, is the doing away with to a great extent of one of the most troublesome questions in connection with timber bridge work, viz., the lodgement of water. No matter how carefully the timbers may be bolted together and painted, water will, after a short time, find its way between the surfaces with its accompanying ill effects; again, in the endeavour to get a close joint along the exposed surface the butting surfaces will oftentimes be made slightly concave, in such cases when the water does penetrate—there being no escape—the evil will be intensified.

The batter braces, which consist of two 14″ by 6½″ timbers bowed and stiffened with hardwood distance pieces have been substituted for principals; thus reducing the horizontal thrust to such an extent as to permit of the introduction of castings in lieu of the large timber butting blocks, with the heavy bolts, previously necessary.

In most of the American Howe trusses counterbraces are introduced, with a view of stiffening laterally the main braces, however the braces in the truss under consideration are comparatively short, and as columns require no lateral stiffening ; counters in the end bays are therefore not provided.

As all the braces in the truss are at the same angle, any shrinkage in the timbers can be taken up by means of the suspension rods ; the iron wedges in the 1886 design are therefore not arranged for in this later type of truss.

The main braces are formed each of two timbers 8″ by 4½″ bowed to prevent warping and twisting and connected together with bolts and hardwood distance pieces, all the timbers being connected to the cast-iron shoes at the top and botton with ⅞″ bolts.

Formerly it was the practice to have the top chord in one piece 16″ by 14″ by 42′ long, which having to be bored for the suspension rods, rendered renewal very costly, if not impracticable. As one of the objects in designing a new type of truss was to permit of renewals, a chord, consisting of two timbers 14″ by 6½″ bowed and stiffened with hardwood distance pieces was adopted, thus securing better timber and giving greater stiffness as a column.

The side braces adopted in previous trusses being a source of inconvenience when footways had to be provided, the author decided to design this chord as a column with a varying load, unsupported in a lateral direction ; none of the text books however, consulted by the author treated of such a case.

The stress in the top chord of a 90 feet span ranges from 69·3 tons in the centre to 27·72 tons in the end bay.

As the maximum stress extends only over a length of 10 feet of the chord, it would be obviously incorrect to take this stress on a column the total length of top chord, nor could it be assumed that this maximum stress was acting only on a column 10 feet long.

The author therefore has dealt with the case in what he submits, is a practical way of looking at the question.

Starting with the end bay there is a stress of 27·72 tons which extends for the whole length of the chord (70 feet). Taking the least diameter, the ratio of length to least diameter is 48 to 1 and the ultimate buckling strength of a timber column of this proportion, being 2·36 tons per square inch, the area required on the point of buckling would be 11·74 inches, whilst at the ends of the column the area required, when on the point of failure by direct crushing would be 5·87 inches.

Setting up these ordinates and plotting in as a parabola, the area shown on diagram, *Plate* 4, is obtained; in the second bay the stress is 48·51 tons extending for a length of 50 feet —but as part of this stress (27·72 tons), has already been provided for, it leaves only 20·79 tons to be dealt with; taking the ratio of length to diameter this gives a column of the proportion of 36 to 1, requiring an area of 6·77 square inches when the column is on the point of buckling at the centre, and an area of 4·4 square inches when on the point of failing by direct chrushing at the ends, the required additional area being shown on the diagram, *Plate* 4.

In the third bay there is a stress of 62·37 tons extending over a distance of 30 feet, 48·51 tons of this stress has already been dealt with, leaving only 13·86 tons to be provided for, proceeding as before, the area shown in green is arrived at; in the middle bay the stress is 69·3 tons extending over 10 feet of which 62·37 tons has been provided for, leaving 6·93 tons to be arranged for.

The whole of the varying stresses having now been dealt with, the heavy dotted black line, represents the total area required when the column would be on the point of failing.

The actual net area of timber provided is 156·16 square inches, *Plate* 4, and as the maximum area required at the centre is only 23·65 square inches, the column has a factor of safety of 6·6 against buckling, irrespective of the stiffness imparted by the splaying of the feet of braces.

The bottom chords of the 1886 type of trusses for 90 feet spans 14″ by 18″ were built up of four 14″ by 4½″ flitches, planed on all surfaces to ensure good butting, the whole being drawn up with ⅞ inch bolts. This is a costly and undesirable design of chord, offering as it does, after a few years, an entrance for water between the flitches, causing decay, which is especially serious on account of the design of truss being such that the bottom chord cannot be renewed, thus necessitating in some cases the replacing of the whole structure, which under other circumstances—with a few new flitches—might have lasted for several years longer.

Again, some of the flitches are 53′ 6″ long and, having to be free of heart and sapwood, are difficult to obtain, and this oftentimes occasioned delay in the erection of the structures, the simple-minded sawmill proprietor supplying all the short and profitable sizes in the bridge, and then pleading inability to supply the more costly flitches.

The bending stress in the bottom chord of the new truss having been eliminated by the omission of intermediate floor beams, only a direct stress has to be provided for, resulting in a considerable reduction in the sectional area of the bottom chord, which consists only of two flitches 12″ by 5″ placed 6 inches apart, thus being always accessible to the brush, and permitting of the renewal of these important members ; again, the longest flitch is only 36 feet, a length easily procurable.

Perhaps the most important connection in a timber truss is the bottom chord joint.

Plate 5, fig. 1, shows the cover adopted for the very old types of truss, which can at a glance be seen to be of little assistance in making up the loss of section caused by the joint in the chord.

Plate 5, fig. 2, shows the cover used in the 1886 type of truss ; this is a much superior connection, but is expensive and difficult to fit.

Plate 5, fig. 3, shows the cover adopted for the new type of truss.

As the two flitches in the bottom chord are independent of one another, the whole stress in each flitch has to be taken by the two 12″ by $\frac{1}{16}$″ wrought-iron plates placed on either side of the beam; on each of these plates four wrought-iron strips 12″ deep by $1\frac{3}{4}$″ wide by 1″ deep are rivetted; these strips are let tightly into the timber and are designed to take up the whole of the stress, and as the stress in each flitch is 31·18 tons and there are four strips giving a total bearing area of 48 square inches, the crushing strain is only ·65 tons per square inch, thus giving a factor of safety of $7\frac{1}{4}$ against crushing, whilst for shearing along the grain a minimum factor of 15 is provided.

Following American practice, the bolts passing through cover plates are not in any way relied upon, being simply provided to keep the plates up to their work, however as the bolts had to be provided the author determined to obtain the benefit of them, and arranged for the bolts to be turned and passed through drilled holes in the plates.

The above joint has also met with the approval of the Engineer-in-Chief for Railways and has been adopted for some of the proposed bridges on the Narrabri-Moree line, whilst in some of the later American railway bridges it has proved successful, despite the fact of it being necessary in some of these pine bridges to arrange for fitting in, eight strips in each plate, instead of four as shown in *Plate* 5.

With this joint, requiring as it does only a straight cut, no difficulty is found in obtaining an almost perfect bearing with ironbark timber, and so far in the 146 joints in the bridges already erected in this Colony, no trouble has been found in effectively making this connection.

The suspension rods, which in the author's design of truss have a minimum diameter of 2″ and $1\frac{1}{2}$″ respectively, are placed on either side of floor beams, and pass through the space between the chords, thus saving the boring of holes through chords and floor

beams, and permitting of easy removal in connection with the system to be adopted in renewing chords.

One of the features of the new type of truss is, that any member can be renewed without staging from below, a matter of importance when deep gorges or fast running streams have to be crossed. Briefly stated, the top and bottom chords being in two pieces, the suspension rods are removed and re-arranged so as to throw the whole weight on one flitch ; there being no strain on the remaining flitch, any member of the top and bottom chord can be replaced with sound timber ; and by slacking the suspension rods and inserting temporary struts, any of the braces can be renewed, whilst the renewal of the cross girders is obviously a simple matter.

In the superstructure of one of the new 90 feet spans carrying a 15 feet deck, there is 500 cubic feet less timber than in the 1886 type of truss, which, in conjunction with the greater ease in framing together (notably in the bottom chord, where no fitting is required) the fewer bolt holes to be bored and the short lengths of timber employed, effects a saving of over £100 in each 90 feet span.

The economy is more marked when it is considered that the old trusses were designed to carry a 15 feet carriageway, whereas the new trusses are designed to carry two 5 feet footways in addition to a 15 feet carriageway. Thus it will be seen that the later design of truss bridge offers greater facilities for traffic at a much reduced cost.

The piers carrying truss bridges vary in accord with local circumstances ; one of the heavy type is that shown in *Plate 6*, consisting of nine vertical piles 12″ by 12″ arranged in groups of four under heels of trusses, also one short vertical pile upstream and two short vertical piles downstream, carrying up and downstream struts. The pier is stayed with wales and braces 12″ by 6″ and internal compression struts 12″ by 12″ seated on hardwood chocks secured to piles with bolts, the chocks being set end on to do away with shrinkage, the previous system of seating butting

blocks on the wales not being satisfactory, the blocks shrinking away from the struts, resulting in a slackness in the bracing.

At Glennies Creek, near Singleton, the superstructure of one of the 90 feet spans cost, erected in position, £450, whilst in the same bridge a pier of the design above described 28 feet 4 inches high from bottom waling to capwales, driven about 16 feet to rock, cost £200. The timber for this bridge was brought from Cape Hawke to Newcastle by sea 61 miles, thence forward by train to Singleton 49 miles, thence by road 9 miles, or a total carriage of 119 miles.

Late in the year 1892, it was decided to erect a new bridge over the Murrumbidgee River at Wagga Wagga. Designs were submitted for a light iron lattice girder bridge, carrying a timber deck resting on iron cross girders, but the amount available being insufficient, the author's design for a timber truss bridge was decided upon, and a contract for construction let to Mr. S. Stokes on 4th October, 1893, at shedule rates, totalling £12,604.

As this bridge is now nearing completion, and, reckoned by the floor space per span (3,165 square feet) is by far the largest timber structure yet attempted in the Colony, a short description may be of interest:—The bridge consists of six timber trusses, resting on iron cylinder piers and concrete abutments, forming three spans each of 110′ 3″ centres, also nine approach spans each of 35 feet. The trusses stand 27′ 1″ apart, centre to centre, and are connected by a top and bottom system of lateral bracing, angle and portal brackets being introduced in the top system. Each truss contains seven panels of 15′ 9″ and being 21 feet deep between centres of triangulations enables full provision to be made for a loaded wool waggon, which requires 17′ 6″ head room. The truss spans are designed to carry a distributed live load of 1·2 tons per foot run, or a concentrated load of 16 tons.

The carriageway is 24′ 4″ whilst one 4′ 6″ footway is arranged for, so that the requirements of the wool traffic will be fully met; a wool waggon measuring 11′ 6″ when loaded and 6′ 6″ when empty.

The wind pressure allowed for is 56lbs. per square foot, on the exposed surfaces of kerbs, stringers, and ends of planking, and on twice the area of the handrails, ends of girders, top and bottom chords, braces and verticals, the whole being taken as an uniform moving load.

Whilst the author is aware that on the occasion of the Dandenong gale, September, 1876, the wind is recorded at the Sydney Observatory to have attained a velocity of 153 miles per hour, equal to a pressure of 115lbs per square foot, yet the author considers there would be no justification for assuming that such a phenomenal pressure would extend over such a large area as that occupied by such a bridge as that under consideration, and in support of this opinion, points to the existing structures throughout the Colony, few if any of which would be now standing if ever subjected to anything approaching even the pressure allowed for in the Wagga Wagga bridge.

The minimum factor of safety adopted for timber in the trusses is 7 for the stresses due to combined dead and live loads. Although this factor may appear to be somewhat liberal, yet it must be borne in mind that the ultimate strength of ironbark has been taken from tests made on small specimens of picked timber, and that a reduction in strength is only to be anticipated in large scantlings, again the flitches being sawn, the grain will run more or less across the line of the sticks, and as defects in timber are so liable to escape even the most severe inspection, it is necessary, in the opinion of the author to make a liberal allowance to cover such contingencies.

The floor system adopted in this bridge presents some novel features, which, so far as the author is aware, have not previously been adopted in any structure in any part of the world. (See *Plate* 7). The main points kept in view were:—

1st. The necessity of having a camber in deck to permit of the quick escape of water.

2nd. The desirability of having a lower lateral system of windbracing, so arranged that the triangulation lines of the

windbracing and the triangulation lines of the truss members would intersect at a common point in the bottom chord.

3rd. The distribution of the load, so as to get each pair of the floor beams to act as one.

4th. The necessity of concentrating the loads at the apices, as, with the Section employed, two 14″ by 7″ timbers, no additional stress was permissable in the bottom chords.

The deck adopted consists of 4″ tranverse planking spiked to 12″ by 6″ longitudinal stringers, seated on the lower lateral struts. The lower lateral strut is 12″ wide by 8″ deep at centre, adzed down on top surface to 6 inches at ends (to give camber in deck), the centre line of strut being placed in the same plane as the centre line of the bottom chord. The ends of the lateral strut are secured to bottom chords by wrought-iron brackets, and to these brackets are attached the diagonal tie rods, the centre lines of which, if produced, would intersect at the centre of bottom chord; the triangulation lines of the wind-bracing and truss members thus intersecting at a common point and avoiding all bending stress.

The lateral struts are tightly dapped one inch over nine 12″ by 4″ sawn packing blocks 2′ 5″ long, resting on the floor beams.

These blocks not only pack the lateral struts up to the same plane as the centre line of chord, but what is of just as much importance, equally distribute the whole load over the pair of floor beams.

With a panel length of 15′ 9″ and a span of 27 feet the resulting load is so great as to necessitate the use of two floor beams, each 14″ wide by 16″ deep, spaced one inch apart (to permit of a current of air and avoid boring for stringer bolts), and connected together with 11 $\frac{7}{8}$″ bolts passing through one inch cast-iron distance washers.

As the overall width of these two floor beams is 2′ 5″ it was impracticable, without fouling the braces and suspension rods, to rest them on the upper edge of the chord. They are therefore

suspended from the chords by sixteen beam hangers $1\frac{3}{8}$ inches diameter passing on either side of the flitches of chords.

The author is of opinion that for timber railway bridges of large span, the floor system above described offers some advantages, inasmuch as shock from trains would be reduced by the lateral strut and distributing blocks acting as a cushion ; whilst the beam hangers being so short a large allowance could economically be made for dynamic action, which action would be materially lessened by the time the main suspension rods were reached.

In connection with the construction of timber bridges, the financial aspect of the question is of the utmost importance. Like all engineers, the author would prefer (if economy had not to be considered) to construct metal bridges, but in a new Colony where the trend of the traffic is likely to be diverted by many circumstances, difficult, if not impossible, to anticipate, it would seem preferable in such localities to construct timber structures with a small capital outlay, rather than spend large sums on works of a more permanent character.

For many years there has been a disinclination in this Colony to build other than permanent traffic bridges out of loan funds, yet as harbour works and railway works, in which timber structures, sleepers, fencing, etc., represent no inconsiderable portion, are built out of loan funds, the author submits there is no reason why traffic bridges should not also be constructed out of borrowed capital, provided it can be shown, first, that they are more economical not only in prime cost but in annual charge, and secondly, that provision be made for their renewal or repayment out of revenue.

It may be urged in these days of cheap steel, that it is against the practice of other parts of the world to construct timber bridges, but in what other country could be found timber with a tensile strength of 8 tons per square inch, a crushing strength of $4\frac{3}{4}$ tons per square inch, and a shearing strength along the grain of 1 ton per square inch : or bridges totally unprotected from the

weather with a life approaching anything like, amongst others, the following:—

Bridge over Cox's River, at Glenroy .....28 years old.
Bridge over Bell River .....32 years old.
Bridge over Macquarie River, at Dubbo .....32 years old.
Bridge over Murrumbidgee River, at Wagga ...33 years old.
Bridge over Duck River, at Parramatta ... ...34 years old.
Bridge over Cudgegong River, at Rylstone.....34 years old.
Bridge at Berrima .....35 years old.
Bridge over Murray River, at Albury.....36 years old.

The first metal bridge in the world, is said to have been erected over the Severn at Colebrook Dale in 1779, this bridge consists of a cast-iron arch of 100 feet span, the structure being thus 116 years old.

Wrought-iron and steel bridges are however of a much later date, and the fixing of the life of such structures, is to a great extent only a matter of conjecture; in connection with this matter Waddell says, "There is no reason why a well-designed iron highway bridge —when properly cared for—should not last for ever." "Under loads which are light and slowly moving compared with those of railway bridges, the iron cannot possibly wear out, and when properly protected from the weather cannot rust."

The author therefore to make everything favorable to the metal bridge in a comparison of its cost, with that of a timber bridge, has assumed the life of the former as infinity; whilst the timber bridge has been taken at only 25 years—a life—it is only reasonable to expect will be much exceeded, with the better type of structure, the more careful inspection of timber, and the greater care in erection that now obtains.

The whole of the timber for the Wagga Wagga bridge was brought from the Northern Rivers to Darling Harbour, about 150 miles by sea, thence by railway to Wagga Wagga 310 miles, or a total carriage of 460 miles.

The contract cost for one timber truss span at Wagga Wagga is £1,300 and the estimated cost of one span of the iron lattice

girder design, complete on bearings was £2,800 (Colonial manufacture). Now, to compare the relative cost of these two bridges on the basis, that the planking in each bridge will require renewal every 12½ years, the remaining timberwork every 25 years and that the ironwork is everlasting, it is necessary to ascertain how much per annum it will take to keep these bridges "trafficable" for ever, in other words to ascertain how much per annum it will cost in each case for interest on the prime cost, tarring, painting, removal of old material and renewing of each portion as it wears out.

Having obtained the annual charge for each bridge, the difference represents the saving effected. The comparison is as follows :—

ANNUAL CHARGE FOR IRON DESIGN.

Item.	Prime Cost.	Interest.		Renewals.	Sinking Fund to provide for removal and renewal of timber.		Maintenance.	Total.
		Rate	Amount.		Life.	Amount.		
	£		£ s. d.			£ s. d.	£ s. d.	£ s. d.
Planking...	180	4 %	7 4 0	£220	12½ yrs.	13 18 2	.....	21 2 2
Stringers...	130	4 ,,	5 4 0	£170	25 ,,	4 1 8	.....	9 5 8
Ironwork...	2490	4 ,,	99 12 0	*Nil.*	Infinity	*Nil.*	.....	99 12 0
Painting ...	.....	.....	.....	.....	.....	.....	60 0 2	60 0 2
	£ 2800					Total annual charge ...		£190 0 0

ANNUAL CHARGE FOR TIMBER DESIGN.

Item.	Prime Cost.	Interest.		Renewals.	Sinking Fund to provide for removal and renewal of timber.		Maintenance.	Total.
		Rate	Amount.		Life.	Amount.		
	£		£ s. d.			£ s. d.	£ s. d.	£ s. d.
Planking...	180	4 %	7 4 0	£220	12½ yrs.	13 18 2	.....	21 2 2
Stringers, trusses, floor-beams and remainder of timber in superstructure	630	4 ,,	25 4 0	£950	25 ,,	22 16 3	.....	48 0 3
Ironwork...	490	4 ,,	19 12 0	*Nil.*	Infinity	*Nil.*	.....	19 12 0
Painting ...	.....	.....	.....	.....	.....	.....	51 5 7	51 5 7
	£ 1300					Total annual charge		£140 0 0

Thus it will be seen that there is a saving of £50 per annum in favour of the timber bridge, which has at 4 per cent. interest, a capital value of £1,250. See *Plate* 8.

The author has also designed timber trusses for spans of 130 feet and 153 feet. The latter truss altogether differs from the Wagga Wagga bridge, four flitches instead of two being placed in the top and bottom chords, and as for purposes of renewal a larger sectional area is provided than is actually required for direct tension, the floor beams can in this case be seated directly on the upper edge of the bottom chord.

The flitches of chords being spaced only three inches apart whilst allowing of a free current of air, and room for painting, permits of the adoption of channel iron gib-plates for suspension rods in lieu of the heavy forgings used at Wagga Wagga, whilst the castings are, from the same cause, much lightened.

Again, in the lower lateral system diagonal timbers and transverse tie rods have been arranged for, which is somewhat more economical than the diagonal tie rods used at Wagga Wagga.

In conclusion the author desires to record his acknowledgments to Mr. Hickson, M.I.C.E., for his courtesy in lending models, plans, and photographs to illustrate the several works mentioned in the foregoing paper.

Discussion.

Mr. Deane said that in a design for a timber bridge, in the first place there was the proportioning of the amount of material in the trusses, and beams to the strain to which they were subjected. That of course should be made as near to theory as possible, although it was hardly possible to strain right up to theory. The different parts should be capable of separate erection, and ought to be put together in a proper manner, for instance, the trusses should be stayed, and should be capable of erection separately; they should be complete in themselves, and braced together before any attempt is made to put on the plat-

form of the bridge. After the trusses are erected then the platform should be added. The old practice used to be on the interlacing principle, leading to something like a Chinese puzzle, and very difficult to deal with in case of renewal. Another point to be considered was the replacement of the separate pieces of the truss, one or other might decay, and they ought to be so fixed that these particular pieces could be easily taken out, and what was of great importance, was the construction of the joints, so that there should be no lodging of water in them, and that they could be examined, and attended to when necessary. With regard to the comparison of the cost of the bridge, the illustration of which the speaker exhibited, with that of Mr. Allan's, the conditions were different, as his was intended for road traffic, and the other for railway purposes. In the road bridge one of the largest items of expense was decking, which the railway bridge was made very much narrower, but having to carry heavier loads was much stronger.

Mr. BURGE—He intended to refer to-night only to the author's comparison between the ultimate cost of timber as against iron or steel in bridge construction. With regard to the cost of the two kinds of structures, a comparison of which was shewn in the table exhibited, the quotation for iron was for colonial manufacture. It might be the view of some people that it was a wise thing to pay something extra in order to encourage manufacture in the Colony, but the extra amount so given was given for that purpose only, and it should not be added to the actual cost of the bridge. Moreover, there was no doubt that Mr. Allan had proved his case, without thus surcharging the ironwork with regard to the preference of the timber over the iron bridge, but if we came to smaller bridges the difference between the permanent design and the temporary one was not so great. In preparing railway estimates he had made the following calculations, which illustrated these views :—

Comparison of timber as against permanent bridge work—assuming no repairs to latter, and in the former about one-fifth,

that is the more exposed parts, required renewal in 11 years, and that the whole had to be rebuilt in 22 years—£100 is provided.

The permanent work is assumed to cost	£100
The timber work one-half, viz.	50
Balance remaining, should the timber bridge be built	£50

Of this balance £7 is placed at compound interest at 4% producing in 11 years £11, with which about one-fifth of the bridge is renewed—£43 remains which, at same interest in 22 years, becomes £102. The whole bridge is now rebuilt for £50, leaving balance of £52 by which the renewal fund is more than kept up. The depreciation is therefore about 4½% per annum on the actual capital expended.

If, therefore, the permanent work costs not more than twice the timber work, it should be preferred from a financial point of view, independently of the objection, in railway work, to renewal as interfering with traffic. This is about the proportion of cost of small openings at 3ft. to 4ft. between concrete or brickwork and timber.

Mr. SMAIL said—one thing he noticed in the new design, was that any member of the truss could be renewed without staging below, while with the old style of bridge when this was being done a temporary one had frequently to be built. The speaker mentioned that in 1876 he erected a bridge of the 1866 design, in which the very best timber procurable was used. It occurred to him then that from the way the bridge was designed, if any part had to be renewed, practically a new bridge had to be built. He thought it would be far better to build small bridges, culverts, &c., with stone or concrete.

Mr. BARRACLOUGH said there was one point he would like to refer to, and it was the method shewn in one of the diagrams of treating the top member as a long column, and he would like to know if Mr. Allan had compared the method which he had employed with the theory of long columns, as the variable load

on the column in question would make the matter a very complex affair.

Mr. STATHAM remarked that there were a great many points in favour of Mr. Allan's design in comparison with the old ones. It was a great defect that so many timbers were in contact in the chord, the damp got into the joints and caused great damage, which practically meant the renewal of the chord, and when the chord was done the bridge was practically done, but in this new design there were a great many improvements. The new method of making up the top chord of smaller scantlings utilised the best part of the timber. Such bridges as these should last 30 years which was the life of the best ones.

Mr. SIMPSON—One thing that struck him was the comparison of prices. It was not a fair thing to compare colonial iron work with timber work, because the former is not of the cheapest kind. He assumed that the price of timber work included the painting, at 4s. per cubic foot, and that of the iron was at 23s. per ton, erected. Then taking Mr. Allan's margin of safety, he found that for the 90ft. span the price of steel work was 7s. per foot of the top chord, as against 3s. for timber, so that these comparative prices were in favour of timber. Personally, he would prefer to deal with a steel or iron structure. As regards the extra prices and renewals, a certain proportion of this timber work had to be renewed in a few years, and it seemed the renewal prices had been calculated upon the same basis as for the original, which was quite incorrect. A timber bridge requires constant inspection, which would add greatly to the cost, and for these reasons he thought he would prefer larger works to be of steel instead of timber.

Mr. BURGE, in explanation, said that the Chairman had remarked upon the cost of renewals being taken as the same as the original provision of the timber, but Mr. Allan had provided for the extra cost. He had put down the cost of the renewal of planking at £220 as against £180 original cost, and of the rest £950 as against £630. As to his own (Mr. Burge's) comparison.

he had made no extra allowance in the railway bridge, and for a very good reason. The material for the original bridge had frequently to bear long road cartage, but the train brought the renewal mentioned to the spot at a very low rate.

Mr. ALLAN, in replying, said that the exhibiting by Mr Deane of the plans of the truss bridges to be erected on the Narrabri-Moree railway line, clearly showed how economically Australian hardwoods could be utilised for railway structures. Mr. Burge, whilst agreeing that in any case a saving in favour of the timber bridge at Wagga Wagga had been shown, thought the timber structure should have been compared with an imported metal bridge. He could not follow Mr. Burge in this, the iron-work in the timber bridge costing £490 was not only manufactured but rolled in the Colony, the iron bridge was also stipulated to be manufactured in the Colony, therefore the estimated actual cost to the country, irrespective of colonial rate of wage, duty, or other similar contributing causes was, Mr. Allan held, the only basis on which a comparison could be made. He could not with confidence make any remarks on Mr. Burge's comparison, as to the relative financial results of small concrete and timber railway culverts, without looking into the question. The experiences of Mr. Smail as to the difficulty of renewing timber in the old type of trusses agreed with his conclusions. The complex character of the theoretical investigation of the strength of a column, carrying different loads throughout its length, remarked upon by Mr. Barraclough, was the reason of reference being made to the case in the hope that information might be given by some of the members on the question. The Author's practical method of treating the subject was based on actual experiment as to the buckling strength of ironbark columns of different ratios of length to diameter.

Mr. Statham's opinion that the using of flitch pieces permitted of matured timber being utilised, thereby ensuring cheap supply and increased durability, is of considerable importance, the benefit of which has been recognised in the new type of trusses.

The Chairman was in accord with popular opinion, that in the long run a steel bridge was cheaper than a timber structure, but the Author pointed out that this popular opinion only held good when pine or other soft wood with a short life was used, in lieu of the much more durable Australian hardwood, and that the Chairman did not support his opinion with the necessary tabulated statement, similar to that submitted by the Author, shewing the comparative cost of interest, renewals, and maintenance of a steel and timber structure. As previously reasoned, Mr. Allan considered it would have been incorrect to compare the Wagga Wagga timber bridge with an iron bridge based on imported prices, but even supposing it possible that by importing the iron bridge the cost could have been reduced by £1,000, there would still be a saving of £10 per annum in annual charge, equal to a capital value at 4% of £250 per span in favour of the timber structure. As the decks in each bridge were similar, the inconvenience to traffic during renewals would be common to both designs, whilst the timber truss members could at the end of twenty-five years (if then decayed) be renewed without interrupting traffic.

FASCINE WORK AS CARRIED OUT BY THE PUBLIC WORKS DEPARTMENT IN NEW SOUTH WALES.

By T. E. BURROWS, L.S.

(Communicated by J. W. Grimshaw, M. Inst. C.E.)

[With Plates 9, 10.]

[*Read before the Engineering Section of the Royal Society of N. S. Wales, October 15, 1895.*]

THE history of embankments for river training purposes in New South Wales, in which the use of fascines of Ti-tree, or similar scrub form part, commenced as far as the author is aware only

ten years back ; but the principle of using fascines of a bushy nature, to bind clay or soil together, has been availed of in many and various instances, either for rough mining dams, or to form mattrasses upon which roads or light tram lines might be carried across swampy ground.

Indeed the first fascine work with which the author was connected, was the construction of a temporary dam of fascines and untempered clay, at a breakaway in the town dam (on western end) at Parramatta about 1880 ; and owing to the force of the water, the river being in flood at the time, it can safely be asserted that only through the use of fascines, for binding the clay, and easing off the power of the stream, the work of repair to the main dam would have been much more expensive than was actually the case.

Fascine work was introduced when Mr. E. O. Moriarty was head of the Harbours and Rivers Department, but the greater portion was carried out under the Engineer-in-Chief, Mr. C. W. Darley.

The credit of the introduction of this class of work into New South Wales is due to Mr. Alfred Williams, M. Inst. C.E., under whom the author had considerable experience, and as Mr. Williams had the advantage of employing this description of river bank protection in England, at the river Severn ; where the range of tide is considerably more than our six feet, he saw to what advantage such work could be put, in the proper alignment of our rivers with their unsightly, useless, and muddy Mangrove flats ; where the use of stone embankments would prove too costly to allow of the work being undertaken ; especially in such places were soft bottoms are met with, as the entrance to the Long Cove Canal at Leichhardt.

Two notable descriptions of fascine work, have been constructed under the supervision of officers in the Public Works Department, and these the author will designate as " Fascine Embankments " and " Fascine Wall."

Fascine Embankments.

The embankment work has been carried out in the following localities, and an approximate statement of the extent of each is also given—

District of Sydney.

Locality.	Length.	Width average.	Height average.	Purpose.	Area reclaimed.
Cook's River...	520 chains	14 feet	9 feet	reclamation	
Shea's Creek[1]	130 „	14 „	9 „	do. & canal	413 acres
Muddy Creek	125 „	14 „	9 „	do. „	
Leichhardt ...	153 „	12 „	9 „	reclamation	81 acres
Callan Park ...	12 „	12 „	9 „	„	5 „
Homebush Bay	210 „	12 „	9 „	„	201 „
Duck River ...	18 „	12 „	9 „	„	41 „
Tarban Creek	16 „	12 „	9 „	„	7½ „

Newcastle District.

	Length.	Width.	Height.	Purpose.
Horseshoe Bend	13 chains	50 feet	30 feet	protection of river bank
Belmore Bridge	17 „	20 „	30 „	„ „

Hawkesbury District.

Sackville Reach	1 chain	8 x 16 feet	„	„

Grafton District.

Public School, 7 chains, 10 x 12 feet, protection of river bank.

Great Marlow Embankment, 60 chains of combination bank, part earthwork only; protection of river bank,

Moruya District.

Moruya River, left incomplete and damaged by floods, length 58 chains, by 14 feet by 9 feet; for training wall purposes.

Of the larger works two may be practically called complete, that at Iron Cove, Callan Park. and also the one at Long Cove; the areas between original high water mark and the present sea face of the embankments, having in each case been filled in to a height of three feet above high water mark by the sand-pumps "Groper" and "Neptune."

[1] Shea's Creek refers only to original creek affected by tidal waters.

The embankment on the western side of the Long Cove Canal has been one of the most difficult of any of these works to deal with, owing to the soft bottom met with in places, which in no case developed when the bank was being constructed, but when the filling was being placed behind.

The weight of filling being greater than the weight of an equal bulk of bank, pressed the soft mud out from beneath the bank into the canal. Section herewith showing the fascine work only slightly disturbed, yet a considerable cavity at back with a corresponding rise in front.

To curb this subsidence of the filling, piling along the toe of the bank has been resorted to, and only one subsidence has since been reported, which is attributable to the piles being of insufficient length to reach beyond the liquid mud underlying the bank, although twenty-six feet long.

In one instance at the mouth of the canal, ballast was tried, but after 3,500 tons of stone had been deposited over an area of 444 square yards, the ballast was still sinking, at the same time displacing the mud as shown by an upheaval in the canal near by.

The following is a detailed description of the method of construction of fascine embankment; after the alignment has been done, and the author can state from severe personal experience, that the setting out of the work is no trifle, when over your knees in mud and still sinking, you are uncertain whether to tell the chainman to come and pull you out, or go on with his distances.

A trench 18 feet wide is made to a depth of 1 foot below low water mark, spring tides, and then the first layer of fascine is laid for a length of about 50 feet with the bushy ends out, bearing in mind that the next layer has to bond over them. A layer of mud 9″ to 1′ deep is then deposited on the fascines, and the work carried up in a similar manner until the requisite height is reached, attention being given to breaking bond with the fascines, by using long or short bundles as required.

A shrinkage of the fascines usually takes place under the weight of the mud, and during the first twelve months amounts to 12″ or 18″, and this shrinkage is made up with silt or other good surface material obtainable.

The first cost of fascine embankment work—at the section given—is under 3′- per cubic yard, inclusive of backing with silt for an average width of 3′: and when the fact that such small subsidence has to be allowed for, and a very small expenditure for maintenance, the embankment may be considered a cheap training wall with a life of over twenty years. Some of this work constructed at Cook's River, nearly ten years ago, bearing out the probability of this statement.

When a scour occurs or the proximity to a steamer's wash is unavoidable, it has been found advisable to face the embankment with fascines, as shown in Section "A": that is, with a liner or stretcher fascine staked down along the face of each layer of silt.

Embankment work of this nature, has been considered as specially liable to damage from fire; but the experience of the author is against this theory, and where the bank has a good top layer of mud, and the fascines are kept to high water spring tides level, it is almost impossible to seriously damage the work by fire. Timber shoots or box drains are used to relieve the banks while in their early stages, from the water pressure caused by falling tides: the shoots being fitted with a hinged flap, which opens outward only; and where large areas are dealt with, or considerable back water has to be released, a self-acting sluice door is used for the same purpose.

In concluding the remarks on embankment work it may be mentioned that where the banks have been constructed by trucking the material for the work ahead, over that recently constructed behind, greater consolidation and security are gained at a very slight additional cost. The Great Marlow Embankment was a combination of earthwork with a fascine face, where height of bank exceeded 5′ and was constructed for protection of river banks from erosion (section herewith).

Fascine Wall Work.

This class of work differs materially from that already described, as this is a thin wall or fence which acts the part of a screen, preventing the silt or similar material deposited at the back of same in a liquified condition, from obtaining access again to the river channel. This work has been constructed at the Myall River, and was carried out by Mr. H. D. Walsh, M. Inst. C.E., under Mr. Darley's instructions, and has been very successful.

It is formed by driving a row of piles, from 6″ to 8″ diameter—of either turpentine or ti-tree with the bark left on—battered slightly inwards, and 3′ apart, and driven 8′ or 10′ into the ground. By using a 12″ × 12″ ironbark ram and steam driving plant on punt, as many as 50 piles could be driven per day, but the author may here remark that where sand is met with, by using a steam pump the piles could be put in much faster and more batter given if required.

Continuous ropes were then formed of pliable ti-tree—from 10′ to 15′ bushes—and as the rope was formed on the punt, it was bound by 14 gauge wire every 18″, and then woven between the piles, and well pressed into place.

It was found necessary to place a small bank of stones, shells, or other suitable material, outside of this fence, to keep out the "Teredo," which are very plentiful in this river.

Plan and sections herewith marked, "B."

Discussion.

Mr. Darley, said, there was nothing very novel about the use of fascine work; it was a very old class of work, but had only been introduced into this Colony during the last ten years; it had been used for enclosing reclamations, training banks, and strengthening river banks, for which latter work it had proved exceedingly satisfactory. The banks of the Mississippi River are protected by endless fascine mattrasses of about 20 ft. wide, laid on the surface, and then loaded with stone. Experience here

proved to him that it would be worse than useless to use fascine for training banks of channels again. The work at Moruya was an utter failure, the fascines were laid on a sand bottom, and when the very first flood took place the sand scoured away and the whole bank floated out to sea, this was anticipated by the then Engineer-in-Chief, Mr. Moriarty, who reported strongly against the use of fascine for such a purpose. The work of this class at Long Cove has not been the success it might have been, piles had lately been driven in, and he believed that they are being pressed forward. He thought that in many cases it would have been cheaper, and more economical to carry out the work with stone, for when the water in front deepens, the stone will run down and check the scour; this is very noticeable at Newcastle, where there is a dyke of a mile and a half in length. This dyke was laid out by the speaker, the construction being commenced at low water, there is now over twenty feet of water close beside it. The stone does not sink with the sand, but as the scour takes place the stone runs down off the face of the dyke and so checks further erosion, and it is a simple matter to make good the loose stone again till the full depth is reached. In this country where in the majority of cases, our coastal harbours have sandy bottoms, fascine work would be quite useless. In the case of some rivers, say the Hunter, some excellent work has been done with fascines, and it has been found a very effective protection against flood, but there it is made of layers of fascine and stone, loaded and coated with stone.

Mr. Deane, said the first cost of work was put down as being under three shillings per cubic yard, but he was under the impression that the work cost a great deal more, and he would like to know from Mr. Darley, where fascine work came cheaper than stone.

Mr. Darley said in reply to Mr. Deane's question, "in what way fascine work came cheaper than stone"? that stone would be very costly to make large dykes of. In our river banks the introduction of the fascine and stones proved itself very effective, where you

have stone only it is very apt to slip forward, owing to excessive weight on the toe when a scour takes place in the river. A mixture of fascine, clay, and stone will stand a heavy rush of water, and has proved to be very successful, it is light, and does not put too much weight on the toe of the bank, that is speaking of a bank of forty to fifty feet in height, alternate layers of stone and fascines have proved very successful. When commencing work at the Tweed River, great pressure was brought to bear to have fascine work introduced, this was not done, as he pointed out what must happen if this class of work were adopted, it would be sure to scour away. It ended that he carried out the work cheaper than any work of a similar kind in the Colony, certainly everything was favourable to this end, and it is now a permanent, lasting, and cheap work. Formerly there were ten to twelve inches of water, but now there is a depth of over fourteen feet, and in cases of that sort stone is the proper thing to use. In cases like Cook's River where stone is scarce and would have been very costly, fascine work was suitable, but if the channel is to be deepened eventually the banks must be faced with stone to make them permanent.

Mr. GRIMSHAW agreed with Mr. Darley's remarks, but did not consider that the author had written the paper with any view of making a comparison between stone and fascine work, or misleading anyone in believing that facine work was superior to stone, but simply with a view of describing where and how fascine work was being used by the Public Works Department of this Colony. Some of the failures mentioned were attributable to the fact that fascine is used on mud flats, or where the bottom is very soft and difficult to deal with. He had no doubt whatever, that for a first class work stone should be used, but in many cases it was quite out of the question on account of the expense, although stone ballast is much cheaper now than it was. Most of the fascine banks had stood very well indeed, though in places where washed by the salt water they could not get any protection from vegetation, which forms a great protection

in fresh water. The slips described by the author have given a great deal of trouble, the slip at Long Cove occurred in spite of piles having been driven twenty feet into the mud, they invariably occurred when the dredges were filling in at the back of the bank, and at low tide. It was the weight at the back of the bank that pushed the mud through and underneath the bank, and the same occurred in a lesser degree in stone dykes. In the case of the Moruya work, mud and silt in the ends of the fascine dyke were washed away by sea waves, leaving the bushes only; and no doubt stone should have been used. Still in his opinion the work was started from the wrong end, it should have been commenced at the shore or upstream end, instead of which it was commenced at the sea end. When the flood came down the river it got at the back of the dyke and washed a great portion of it away. In swampy country, such as Cook's River, an immense amount of stone would have been absorbed as there is no saying to what depth it would have sunk in the soft mud. In the case of Rozelle Bay it sank over eight feet, and in Long Cove it disappeared altogether. There was no more expense in keeping the fascine work in good order than was experienced with the sides of an ordinary river, when once the reclamation was complete. He was quite of opinion that the facing of fascine banks should be of stone, if possible, and where there was a rocky or hard bottom stone should be used entirely.

Mr. P. ALLAN said, where you have to dredge a channel to a considerable depth, it is inadvisable to use anything but stone, as he believed it to be very doubtful whether successful work could otherwise be done.

Mr. SIMPSON said that he quite agreed with the remark that more is sometimes to be learned from failure than from success, but as it has been pointed out by members there are cases in which fascine work would be quite inappropriate, and in other cases fascine work should undoubtedly be adopted.

Mr. BURROWS in reply, stated, that the primary reason of this paper was to give information, as to the purposes for which fascine

work is used in New South Wales, and not for any comparison with stone embankments. For if stone can be used, from an economical point of view it should be. In the case of Long Cove, at one point stone was used with no success, as it was found that the stones kept sinking. Piles were afterwards used, and were put down to a depth of forty-seven feet, the last strata was softer than the upper crust, so that the building of a stone dyke at a one to one slope section, would cost infinitely more than the fascine work. The slips occurred through using the bank as a dam, a purpose for which it was never intended, large lakes of water were formed behind them by the use of sand pumps. This water would have at least a six feet head at low tide. Mr. Grimshaw pointed out in the case of the Moruya work, and he agreed with him, that it was started at the wrong place, and that it had not only the ordinary run of the tide but when a flood came there was nothing to protect it from the scour, consequently the water got both back and front of it, and gave it no chance whatever. The dykes of Holland are constructed largely of mud, and only faced with mattrasses of something similar in character to ti-tree ; weighted with stone or rip-rap, certainly they have much flatter slopes, which are necessary on account of their abutting on the open sea. An instance of the cost of stone in a finished dyke is Rozelle Bay, this is six feet wide on top, with a one to one slope on both sides, the bottom is fairly soft, the stone used was tipped over the ends of the bank, and the cost of stone here compared to fascine work, allowing for a subsidence of the latter of three feet, would be about two to one. He found that the stones had displaced the silt to a depth of from something like ten to fifteen feet, the average being eleven feet for a length of 1,650 feet of dyke. Fascines sometimes give a very ragged appearance to a bank, and the cost of facing up is about fifteen shillings per rod, but when a bank will stand about five years without having anything done to it, this extra payment for maintenance is very inconsiderable. The percentage of shrinkage is about 15% on the section of the bank during the first twelve months.

INDEX.

A

Abercromby Fund ... 3, 7, 553
Acacia Bakeri 393, 399
—— *Oswaldi* 393, 398
—— *retinoides* 393, 399
—— *Maideni* 394, 400
Additions to the Library ... 572
Aeronautical work 40
Allan, Percy, A.M.I.C.E., Timber bridge construction in New South Wales ... ... I.
Albizzia pruinosa... ... 394, 400
Aluminium succinate 325
Amygdaloidal trachyte ... 484
Analysis of water from Wyalong 406
Ancient Antarctic life 278
Andesite, glassy augite ... 474
—— augite 485
—— basaltic 475
—— vesicular glass 475
Angophora lanceolata 31, 37, 38, 39, 40
Anniversary Address 1
Antarctic exploration, history of 462
—— rocks 461
Antimonite 316
Apatite, plumbiferous 316
Arabinose 395
Aromadendrin 40
Artesian water in N. S. Wales 7
—— —— in rocks other than Cretaceous 408
Astringent exudations... ... 401
Australian black snake ... 146
—— gums 393
—— kinos 394
—— myrtaceous kinos... ... 30
—— tiger-snake 157
—— vegetable exudations ... 393
—— weather, types of... ... 513
i.—Moving Anticyclones
ii.—Monsoonal Rain Storm
iii.—Development of a Cyclonic Storm in Low Latitudes from a Monsoonal Depression
iv.—Development of a Cyclonic Storm in High Latitudes from a Monsoonal Depression
v.—Conditions favourable for Thunderstorms
vi.—Cyclonic Thunderstorms
vii.—Vertical and nearly straight Isobars
viii.—Cyclones from North-west
ix.—Cyclones from North-east
x.—Tornadoes
xi.—South-east Gales
xii.—Development of Cyclones from a A Depression
xiii.—Westerly Winds
xiv.—Southerly Bursters
xv.—Black North-easter
xvi.—Winds Blowing against Isobars
xvii.—Summer Anticyclone
xviii.—Winter Anticyclone
xix.—Square Headed A Depression
xx.—Advent of an Antarctic Storm

PAGE

"Axe-breaker" 394

B

Barraclough, S. H., B.E., M.M.E., the tensile and compressive strength of magnesium ... 453
Barklyite... 317
Basalt, olivine 476, 488
Basaltic andesite 475
Basic tuff 481
Beryl 318
Bismuth associated with selenium 404
Black-snake 146
Blood and blood vessels, action of snake venom on 151
"Blythesdale Braystone" 411, 413, 414
Borchgrevink, C. E., Antarctic rocks collected by 461
Bosistoa sapindiformis ... 393, 394
Bouchardatia neurococca ... 396
Bridge (timber) construction in New South Wales ... ... I.
"Brittle gum" 401
"Broad-leaved Sally"... ... 400
Building and Investment Fund 553
Burge, C. O., M. Inst. C.E., On the preparation of Engineering specifications and general conditions for large works 567
Burrows, T. E., L.S., Fascine work as carried out by the Public Works Department in New South Wales 568, xx.

C

PAGE

"Cabbage gum" 401
Calcium tungstate 323
Capparis nobilis 393, 397
Cape Adare, geological specimens from 471
Cæsalpinia coriaria 37
Cellular Kites 26
Chrysocolla 318
Circular curves, easing of ... 51
Clarke Medal 5
—— Memorial Fund ... 3, 553
Climate of Lord Howe Island... 512
Crocoisite 318
Cubic parabola ... 51, 54
Curran, Rev. J. Milne, Geological laboratory notes No. 1 404
i On selenium associated with gold and bismuth from Mount Hope, N. S. Wales 404
ii. On a graphitic slate from Yalcogrin, N. S. Wales . 405
iii. Analysis of water from Wyalong 406
iv. On the trachytes of the Canoblas and the Warrumbungle Mountains ... 407

D

David, Prof. T. W. E., B.A., F.G.S., Notes on Antarctic rocks collected by Mr. C. E. Borchgrevink 461
Part i. Introductory Notes about Antarctica 461
Part ii. Petrology of the rocks from Cape Adare, Victoria Land, and from Possession Island 471
Summary 490
Deane, H., M.A., M. Inst. C.E., Some recent Engineering developments in England and America 567
Dick, J. A., M.D., Notes on a case of maliguant disease of the lung 570
Diphtheria, Resorcin treatment 570
"Divi Divi" 37
Doane, Rev. E. T., the late, a comparison of the languages of Ponape and Hawaii 420
Dolerite, olivine... .. 476, 477
Duboia russellii 269
"Dumbartonshire" the dereliet 284

E

Echidna, embryology and development 7
Ellagic acid from *Angophora lanceolata* 37
Ellagic acid from "Divi Divi" 37
Engineering Section ... 553, 566
—— developments in England and America 567
—— specifications and general conditions for large works, the preparation of 567
Eucalyptus hæmastoma ... 394, 401
—— *hemiphloia* 31, 33, 38
—— *Planchoniana* ... 394, 401
Eudesmin 32
—— chemical composition ... 35
Exhibits at Monthly Meetings 557, 560, 564
Exudations, astringent ... 401
—— Australian vegetable ... 393

F

Fahlerz 319
Faithfull, R. L., M.D., Significance of albuminuria more especially as regarded by medical examiners for Life Insurance 570
Fascine work in N.S. Wales 568, xx.
Folk-songs, Samoan 366
Fraser, John LL.D., some folk-songs and myths from Samoa 366
xxxv.-xxxvii. The 'Senga' 366
xxxviii. The story of Moi-u-u-le-Apai and her husband Tui-Fiti, the King of Fiji 378
xxxix. Valua and Tiapa 390

G

Galena zinciferous 320
Garnetiferous-granulitic-aplite 471
Geijera Muelleri 393, 394, 396, 397
General Account 553
Geological laboratory notes ... 404
Glassy augite andesite... ... 474
"Glue gum" 402
Gold associated with selenium 404
—— in sea-water 335
—— —— removal by Muntz-metal sheathing 350
Graphitic slate 405
Grevillea robusta... 325
Gums, Australian 393
Gum-resins 394, 402

H

Hall, Edgar, note on the origin of Malachite 416
Hargrave, Lawrence, paper on aeronautical work 40

PAGE

Hawaiian language 420
Hedley, C., F.L.S., Considerations on the surviving refugees in Austral lands of ancient Antarctic life ... 278
Hoplocephalus curtus 157
Hunt, Henry A., Types of Australian weather 513
Huxley Memorial 564
Hydrous copper silicate ... 318

I

Icebergs in the Southern ocean 286
Ice, black or discoloured ... 562
Ilmenite 319

J

Jamieson, Sydney, B.A., M.B., On some cases illustrating the effects of syphilis on the central nervous system ... 571

K

Kerosene shale (so-called) N.S.W. 7
Kiddle, H. C., F. R. Met. Soc., Notes on the rainfall of the Southern Riverina, 1872–1894 492
Kinos, Australian ... 394, 401
—— myrtaceous 30
Knibbs, G. H., L.S., The history, theory and determination of the viscosity of water by the efflux method 77

L

Languages of Ponape and Hawaii 420
Lemon, wild 397
Library 5
—— additions to 572
Limburgite 479, 480
Limestone with cone-in-cone structure 321
Liversidge, Prof. A., M.A., F.R S., On the amount of gold and silver in sea-water ... 335
—— On some New South Wales and other minerals (Note No. 7) 316
—— The removal of silver and gold from sea-water by Muntz metal sheathing ... 350
Lord Howe Island, climate of 512

M

PAGE

Magnesium, tensile and compressive strengths of ... 453
Malachite, origin of 416
Maiden, J. H., F.L.S., A contribution to the chemistry of Australian myrtaceous kinos 30
—— Contributions to a knowledge of Australian vegetable exudations, No. 1. ... 393
—— On a natural deposit of aluminium succinate in the timber of *Grevillea robusta*, R. Br... 325
Martin, C. J., B. Sc., M.B., *Lond.* On the physiological action of the venom of the Australian black snake *(Pseudechis porphyriacus)* ... 146
i. Introduction. 146
ii. Methods of introduction of the venom 147
iii. Action of venom on the blood and blood vessels 151
iv. Effect of venom on the circulatory mechanism ... 208
v. Effect of venom on the nervous system 240
vi. Effect of venom on the respiratory mechanism ... 256
vii. Effect of venom on the body temperature 266
viii. Further pathological effects 267
ix. Comparison of experimental results with the symptoms of *Pseudechis* poisoning in man 275
Appendix—The toxic value of venoms 277
Medal, Society's award of ... 6
Medical Section... 555
Medicosma Cunninghamii 394, 402
Melicope neurococca 393, 396, 397
Merfield, C. J., The cubic parabola as applied to the easing of circular curves on railway lines 51
Meteor of May 7th, 1895 ... 499
Mica schist 481
Milford, F., M.D., Notes on the treatment of diptheria with Resorcin 570
"Miljee" 398
Minerals, N.S. Wales and other 316
Mineral substances, new ... 48
Molybdenite 322
Morus alba 332
Myths, Samoan 366

N

New mineral substances ... 48
New South Wales minerals ... 316

O

Obituary 1894 1
Olivine basalt ... 476, 477, 488
—— -dolerite 476
Original Researches 5

P

Pentaceras australis ... 393, 397
Pepper tree ... — ... 456
Pittman, E. F., A.R.S.M., Notes on two new mineral substances from the Australian Broken Hill Consols Mine 48
Pittosporum undulatum 456
Platypus, embryology and development 7
Pocillopora alcicornis 353
Ponape language 420
Possession Island, geological specimens from 484
Proceedings of the Sections ... 566
—— of the Society 552
Proustite... 322
Pseudechis porphyriacus 146

R

Railway lines, easing of curves on 51
Rainfall in Southern Riverina 492
Ray, Sidney H., Notes and illustrations on a comparison of the languages of Ponape and Hawaii by the late Rev. E. T. Doane 420
Rennie, G. E., B.A., M.D., On death after head injuries... 570
Rocks, Antarctic 461
Russell, H. C., B.A., C.M.G., F.R.S., Icebergs in the Southern Ocean 286
—— The climate of Lord Howe Island 512
—— The great Meteor of May 7 1895 499

S

Samoan Folk-songs and Myths 366
Scheelite 323
Schinus molle 456
Schofield, J. A., F.C.S., A.R.S.M., Notes on Antarctic rocks... 461
Schizomeria ovata ... 394, 401
"Scrub Hickory" 397
Sea-water, gold and silver in... 335
Sections, Proceedings of the .. 566
Selenium associated with gold and bismuth 404
Senga bird 366
Silver in sea-water ... 335, 349
—— removal by Muntz metal sheathing 350
—— sulphursenide 322
Smail, J. M., M. Inst. C.E., Notes on the underdraining of the Filter Beds at the Botany Sewage Farm 568
Smeeth, W. F., M.A., A.R.S.M., Notes on Antarctic rocks ... 461
Smith, Henry G., A contribution to the chemistry of Australian myrtaceous kinos 30
—— On a natural deposit of aluminium succinate in the timber of *Grevillea robusta*, R.Br. 325
—— Contributions to a knowledge of Australian vegetable exudations, No. 1 393
Southern Ocean, icebergs in ... 286
"Stinkwood" 400
Struthiolaria ornata 285
—— *mirabilis* 285

T

Teniopteris Daintreei 409, 410, 412
Thinnfeldia odontopteroides ... 410
Threlfall, Prof. M.A., Note on some products from the fruit of *Pittosporum undulatum* and from the leaves of the pepper tree *Schinus molle* ... 456
—— Presidential Address ... 1
Tiger-snake 157
Timber bridge construction in New South Wales 568
Tinstone crystals 323
Topaz 324
Trachyte amygdaloidal ... 484
Trachytes of the Canobolas and Warrumbungle Mountains 407

V

Vegetable exudations 393
Venoms, toxic value of ... 277
Venom, action on the blood ... 151
—— of the Australian black snake... 146
—— methods of introduction... 147

PAGE

Venom, effect on the circulatory mechanism 208
—— —— body temperature ... 266
—— —— nervous system ... 240
—— —— respiratory mechanism 256
Vipera berus 209
Viscosity of water 77

W

Water, artesian in N. S. Wales 7
—— —— in rocks other than Cretaceous 408
Water from Wyalong, analysis of 406
—— viscosity of 77
Weather, Australian 513
"White gum" 401
White mulberry tree 332
Wild lemon 397

Z

Zinciferous galena 320

EXCHANGES AND PRESENTATIONS

MADE BY THE

ROYAL SOCIETY OF NEW SOUTH WALES, 1895.

The Journal and Proceedings of the Royal Society of N.S.W. for 1895 Vol. XXIX., has been transmitted through the New South Wales Government Board for International Exchanges, Public Library, Sydney :—

The Smithsonian Institution, Washington, United States, America, and Messrs. George Robertson & Co., 17 Warwick Square, Paternoster Row, London, E.C., have kindly undertaken to receive and forward to Sydney all communications and parcels intended for the Royal Society of New South Wales.

Presentations to the Society are acknowledged by letter, and in the Society's Annual Volume.

* Exchanges of Publications have been received from the Societies and Institutions distinguished by an asterisk.

Africa.

1 TUNIS ... ...*Institut de Carthage.

Argentine Republic.

2 CORDOBA ... ...*Academia Nacional de Ciencias.
3 LA PLATA... ...*Directeur-Général de Statistique de la Province de Buénos Ayres.
4 „ ... ...*Museo de La Plata, Provincia de Buenos Aires.

Austria—Hungary.

5 AGRAM (Zagrab) ...*Société Archéologique Croate.
6 BISTRITZ (in Siebenbürgen) } *Direction der Gewerbeschule.
7 CRACOW ... ...*Académie des Sciences.
8 GRATZ ... ...*Naturwissenschaftliche Vereins für Steiermark in Graz.
9 PRAGUE ... ...*Königlich Bohmische Gesellschaft der Wissenschaften.
10 TRENCSIN ... ...*Naturwissenschaftliche Verein des Trencsiner Komitates.
11 TRIESTE ... ...*Museo Civico di Storia Naturale.
12 „ ... ...*Società Adriatica di Scienze Naturali.
13 VIENNA ... .. *Anthropologische Gesellschaft.
14 „ ... ...*Kaiserliche Akademie der Wissenschaften.
15 „ ... ...*K. K. Central-Anstalt für Meteorologie und Erdmagnetismus.
16 „ ... ...*K. K. Geographische Gesellschaft.
17 „ ... ...*K. K. Geologische Reichsanstalt.
18 „ ... ...*K. K. Gradmessungs-Bureau.
19 „ ... ...*K. K. Naturhistorische Hofmuseums.
20 „ ... ...*K. K. Zoologisch-Botanische Gesellschaft.
21 „ ... ...*Section für Naturkunde des Osterreichischen-Touristen Club.

Belgium.

22 BRUSSELS ... ...*Académie Royale des Sciences, des Lettres et de Beaux Arts.

23	Brussels	...	...*Musée Royale d'Histoire Naturelle de Belgique.
24	,,	...	...*Observatoire Royale de Bruxelles
25	,,	...	...*Société Royale Malacologique de Belgique.
26	Liége	...	...*Société Géologique de Belgique.
27	,,	...	...*Société Royale des Sciences de Liége.
28	Luxembourg		...*Institut Royale Grand-Ducal de Luxembourg.
29	Mons	...	...*Société des Sciences, des Arts et des Lettres du Hainaut.

Brazil.

30	Rio de Janeiro		...*Observatoire Impérial de Rio de Janeiro.

Chili.

31	Santiago	...	...*Sociedad Cientifica Alemana.

Denmark.

32	Copenhagen		...*Société Royale des Antiquaires du Nord.

France.

33	Bordeaux	...	...*Académie Nationale des Sciences, Belles-Lettres et Arts.
34	Caen	...	...*Académie Nationale des Sciences, Arts et Belles-Lettres.
35	Dijon	...	...*Académie des Sciences, Arts et Belles-Lettres.
36	Havre	...	...*Société Géologique de Normandie.
37	Lille	...	...*Société Géologique du Nord.
38	Marseilles		...*Faculté des Sciences de Marseille.
39	Montpellier		...*Académie des Sciences et Lettres.
40	Nantes	...	...*Société des Sciences Naturelles de l'Ouest de la France.
41	Paris	...	...*Académie des Sciences de l'Institut de France.
42	,,	...	... Bibliothèque de l'Université à la Sorbonne.
43	,,	...	...*Comptoir Géologique de Paris.
44	,,	...	...*Depot des Cartes et Plans de la Marine.
45	,,	...	...*Ecole d' Anthropologie de Paris.
46	,,	...	...*Ecole Nationale des Mines.
47	,,	...	... Ecole Normale Supérieure.
48	,,	...	...*Ecole Polytechnique.
49	,,	...	... Faculté de Médecine de Paris.
50	,,	...	...**Feuille des Jeunes Naturalistes.*
51	,,	...	...*Institut Pasteur.
52	,,	...	...*Musée d'Histoire Naturelle.
53	,,	...	...*Ministère de l'Instruction Publique, des Beaux Arts, et des Cultes.
54	,,	...	
55	,,	...	...*Observatoire de Paris.
56	,,	...	...**Revue de l' Aéronautique.*
57	,,	...	... Société Botanique.
58	,,	...	...*Société d'Anatomie.
59	,,	...	...*Société d' Anthropologie.
60	,,	...	...*Société de Biologie.
61	,,	...	... Société de Chirurgie de Paris.
62	,,	...	...*Société d' Encouragement pour l' Industrie Nationale.
63	,,	...	...*Société Entomologique de France.
64	,,	...	...*Société Française de Minéralogie.

65 PARIS ... ...*Société Française de Physique.
66 „ ... ...*Société de Géographie.
67 „ ... ...*Société Géologique de France.
68 „ ... ... Société Météorologique de France.
69 „ ... ... Société Philotechnique.
70 „ ... ...*Société Zoologique de France.
71 ST. ETIENNE ...*Société de l' Industrie Minérale.
72 TOULOUSE ...*Académie des Sciences, Inscriptions et Belles-Lettres.
73 VILLEFRANCHE-SUR-MER (Alp. Mar.) ... } Laboratoire de Zoologie.

Germany.

74 BREMEN .. ...*Naturwissenschaftliche Vereine zu Bremen.
75 BERLIN ... ... Deutsche Chemische Gesellschaft.
76 „ ... ...*Gesellschaft für Erdkunde.
77 „ ... ...*Königlich Preussische Akademie der Wissenschaften.
78 „ ... ...*Königlich Preussische Meteorologische Instituts.
79 BONN ... ...*Naturhistorischen Vereins der Preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück.
80 BRUNSWICK ...*Vereins für Naturwissenschaft zu Braunschweig.
81 CARLSRUHE ...*Grossherzoglich-Badische Polytechnische Schule.
82 „ ...*Naturwissenschaftlicher Verein zu Carlsruhe.
83 CASSELL ... ...*Verein für Naturkunde.
84 CHEMNITZ ...*Naturwissenschaftliche Gesellschaft zu Chemnitz.
85 DRESDEN ... ...*Königliches Mineralogisch und Praehistorisches Museum.
86 „ ... ...*Offentliche Bibliothek.
87 „ ... ...*Statistische Bureau des Ministeriums des Innern zu Dresden.
88 „ ... ...*Vereins für Erdkunde zu Dresden.
89 ELBERFELD ...*Naturwissenscheftlicher Verein in Elberfeld.
90 FRANKFURT A,M ...*Senckenbergische Naturforschende Gesellschaft.
91 FREIBERG (Saxony) Königlich-Sachsische Berg-Akademie.
92 FREIBURG (Baden) *Naturforschende Gesellschaft.
93 GIESSEN ... ...*Oberhessische Gesellschaft für Natur-und-Heilkunde.
94 GÖRLITZ ... .. *Naturforschende Gesellschaft in Görlitz.
95 GÖTTINGEN ...*Königliche Gesellschaft der Wissenschaften in Göttingen.
96 HALLE, A.S. ...*Kaiserliche Leopoldina—Carolina Akademie der Deutschen Naturforscher.
97 HAMBURG... ...*Deutsche Meteorologische Gesellschaft.
98 „ ... ...*Deutsche Seewarte.
99 „ ... ...*Geographische Gesellschaft in Hamburg.
100 „ ... *Naturhistorische Museum
101 „ ... *Verein für Naturwissenschaftliche Unter-haltung in Hamburg.
102 HEIDELBERG ...*Naturhistorisch Medicinische Verein zu Heidelberg.
103 JENA ... ...*Medicinisch Naturwissenschaftliche Gesellschaft.
104 KÖNIGSBERG ...*Konigliche Physikalisch-Okonomische Gesellschaft.

105 LEIPZIG ... ...*Königliche Sächsische Gesellschaft der Wissenschaften.
106 „ ... ...*Vereins für Erdkunde.
107 LUBECK ... ...*Naturhistorische Museum.
108 MARBURG... ...*Gesellschaft zur Beförderung der gesammten Naturwissenschaften in Marburg.
109 „ ... ...*University.
110 METZ ... ...*Vereins für Erdkunde zu Metz.
111 MULHOUSE ...*Société Industrielle de Mulhouse.
112 MUNICH ... ...*Königlich Bayerische Akademie der Wissenschaften in München.
113 „ ... ... Société Botanique Bavaroise.
114 STUTTGART ...*Königliches Statistische Landesamt.
115 „ ... ...*Verein für Vaterländische Naturkunde in Württemberg.
116 „ ... ...*Württembergische Vereins für Handelsgeographie.

Great Britain and the Colonies.

117 BIRMINGHAM ...*Birmingham and Midland Institute.
118 „ ...*Birmingham Philosophical Society.
119 BRISTOL ... ...*Bristol Naturalists' Society.
120 CAMBORNE .. *Mining Association and Institute of Cornwall.
121 CAMBRIDGE ...*Philosophical Society.
122 „ ... Public Free Library.
123 „ ...*Union Society.
124 „ .. University Library.
125 KEW ... ...*Royal Gardens.
126 LEEDS ... ...*Leeds Philosophical and Literary Society.
127 „ ... ...*Yorkshire College.
128 LIVERPOOL ...*Literary and Philosophical Society.
129 LONDON ... ...*Aëronautical Society of Great Britain.
130 „ ... ... Agent-General (two copies).
131 „ ... ...*Anthropological Institute of Great Britain and Ireland.
132 „ ... ...*British Museum (Natural History).
133 „ ... ... Chemical Society.
134 „ ... ... Colonial Office, Downing Street.
135 „ ... ...*Editor, *Encyclopædia Britannica*, 4 Soho Square, W.
136 „ ... ... Institute of Chemistry of Great Britain and Ireland.
137 „ ... ...*Institution of Civil Engineers.
138 „ ... ...*Institution of Mechanical Engineers.
139 „ ... ...*Institution of Naval Architects.
140 „ ... ...*Iron and Steel Institute.
141 „ ... ...*Library, South Kensington Museum.
142 „ ... ...*Linnean Society.
143 „ ... ... London Institution.
144 „ ... ...*Lords Commissioners of the Admiralty.
145 „ ... ...*Meteorological Office.
146 „ ... ...*Mineralogical Society.
147 „ ... ... Museum of Practical Geology.
148 „ ... ... Patent Office Library.
149 „ ... ...*Pharmaceutical Society of Great Britain.
150 „ ... ...*Physical Society of London.
151 „ ... ...*Quekett Microscopical Club.

152	LONDON ...	...*Royal Agricultural Society of England.
153	,, ...	...*Royal Astronomical Society.
154	,, ...	...*Royal College of Physicians.
155	,, ...	...*Royal College of Surgeons.
156	,, ...	...*Royal Colonial Institute.
157	,, ...	...*Royal Geographical Society.
158	,, ...	...*Royal Historical Society.
159	,, ...	...*Royal Institution of Great Britain.
160	,, ...	...*Royal Meteorological Society.
161	,, ...	...*Royal Microscopical Society.
162	,, ...	... Royal School of Mines.
163	,, ...	...*Royal Society.
164	,, ...	... Royal Society of Literature.
165	,, ...	...*Royal United Service Institution.
166	,, ...	...*Sanitary Institute of Great Britain.
167	,, ...	...*Society of Arts.
168	,, ...	... University of London.
169	,, ...	...*War Office (Intelligence Division).
170	,, ...	...*Zoological Society.
171	MANCHESTER	...*Conchological Society.
172	,,	...*Literary and Philosophical Society.
173	,,	...*Manchester Geological Society.
174	,,	... Owens College.
175	MIRFIELD	...*Yorkshire Geological and Polytechnic Society.
176	NEWCASTLE-UPON-TYNE...	...*Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne.
177	,,	...*North of England Institute of Mining and Mechanical Engineers.
178	,,	... Society of Chemical Industry.
179	OXFORD ...	...*Bodleian Library.
180	,, ...	...*Radcliffe Library.
181	,, ...	...*Radcliffe Observatory.
182	PENZANCE	...*Royal Geological Society of Cornwall.
183	PLYMOUTH	...*Plymouth Institution and Devon and Cornwall Natural History Society.
184	WINDSOR ...	... The Queen's Library.

CAPE OF GOOD HOPE.

185	CAPE TOWN	...*South African Philosophical Society.

CEYLON.

186	COLOMBO ...	...*Royal Asiatic Society, (Ceylon Branch).

DOMINION OF CANADA.

187	HALIFAX, (Nova Scotia)	*Nova Scotian Institute of Science.
188	HAMILTON (Ont.)	*Hamilton Association.
189	MONTREAL	...*Natural History Society of Montreal.
190	,, ...	...*Royal Society of Canada.
191	OTTAWA ...	...*Geological and Natural History Survey of Canada.
192	QUEBEC ...	...*Literary and Historical Society.
193	TORONTO ...	...*Canadian Institute.
194	,, ...	...*University.
195	WINNIPEG	...*Manitoba Historical and Scientific Society.

INDIA.

196	CALCUTTA	...*Asiatic Society of Bengal.
197	,, ...	...*Geological Survey of India.

IRELAND.

198 DUBLIN ... ...*Royal Dublin Society.
199 „ ... ...*Royal Geological Society of Ireland.
200 „ ... ...*Royal Irish Academy.

JAMAICA.

201 KINGSTON... ...*Institute of Jamaica.

MAURITIUS.

202 PORT LOUIS ...*Royal Society of Arts and Sciences.
203 „ ... Société d'Acclimatation de l' Ile Maurice.

NEW SOUTH WALES.

204 RICHMOND ... Hawkesbury Agricultural College.
205 SYDNEY ... ...*Australian Museum.
206 „ ... .. *Department of Mines and Agriculture.
207 „ ... ...*Department of Public Instruction.
208 „ ... ...*Engineering Association of New South Wales.
209 „ ... ...*Government Statistician.
210 „ ... ...*Linnean Society of New South Wales.
211 „ ... ...*Mining Department.
212 „ ... ... N. S. Wales Government Railways Institute.
213 „ ... ...*Observatory.
214 „ ... ...*Public Library.
215 „ ... ...*Public Works Department.
216 „ ... ...*Royal Geographical Society of Australasia (New
217 „ ... South Wales Branch).
218 „ ... ... School of Arts.
219 „ ... ...*Technological Museum.
220 „ ... ...*United Service Institution of New South Wales.
221 „ ... ...*University.

NEW ZEALAND.

222 AUCKLAND ...*Auckland Institute.
223 CHRISTCHURCH ... Philosophical Institute of Canterbury.
224 DUNEDIN .... Otago Institute.
225 WELLINGTON ...*Colonial Museum.
226 „ ...*New Zealand Institute.
227 „ ...*Polynesian Society.

QUEENSLAND.

228 BRISBANE... *Acclimatization Society of Queensland.
229 „ ... ...*Geological Survey of Queensland.
230 „ ... ... Parliamentary Library.
231 „ ... ...*Queensland Museum.
232 „ ... ...*Royal Geographical Society of Australasia (Queensland Branch).
233 „ ... ...*Royal Society of Queensland.

SCOTLAND.

234 ABERDEEN .. *University.
235 EDINBURGH ...*Edinburgh Geological Society.
236 „ ... ..*Highland and Agricultural Society of Scotland.
237 „ ... ...*Royal Botanic Garden.
238 „ ... ...*Royal Observatory.
239 „ ... ...*Royal Physical Society.

240 EDINBURGH ...*Royal Scottish Geographical Society.
241 „ ...*Royal Society.
242 „ ...*University.
243 GLASGOW ... ...*Geological Society of Glasgow.
244 „ ... ...*Philosophical Society of Glasgow.
245 „ ... ...*University.
246 ST. ANDREWS ...*University.

SOUTH AUSTRALIA.

247 ADELAIDE... ...*Geological Survey of South Australia.
248 „ ... ... Government Botanist.
249 „ ... ...*Government Printer.
250 „ ... ...*Observatory.
251 „ ... ...*Public Library, Museum, and Art Gallery of South Australia.
252 „ ... ...*Royal Geographical Society of Australasia (South Australian Branch).
253 „ ... ...*Royal Society of South Australia.
254 „ ... ...*University.

STRAITS SETTLEMENTS.

255 SINGAPORE .. *Royal Asiatic Society (Straits Branch).

TASMANIA.

256 HOBART ... ...*Royal Society of Tasmania.
257 LAUNCESTON ...*Geological Survey of Tasmania.

VICTORIA.

258 BALLARAT ...*School of Mines and Industries.
259 MARYBOROUGH ... District School of Mines, Industries and Science.
260 MELBOURNE ...*Field Naturalists' Club of Victoria.
261 „ ...*Government Botanist.
262 „ ...*Government Statist.
263 „ ...*Mining Department.
264 „ ...*Observatory.
265 „ ...*Public Library.
266 „ ...*Registrar-General.
267 „ ...*Royal Geographical Society of Australasia (Victorian Branch).
268 „ ...*Royal Society of Victoria.
269 „ ...*University.
270 „ ...*Victorian Institute of Surveyors.
271 „ ...*Working Men's College.
272 STAWELL ... ...*School of Mines, Art, Industry, and Science.

WESTERN AUSTRALIA.

273 PERTH ... ...*Museum.

Hayti.

274 PORT-AU-PRINCE ... Société de Sciences et de Géographie.

Italy.

275 BOLOGNA ... ...*R. Accademia delle Scienze dell'Istituto.
276 „ ... ... Università di Bologna.
277 FLORENCE... ...*Società Africana d'Italia (Sezione Fiorentina).

278 FLORENCE ...*Società Entomologica Italiana.
279 „ ...*Società Italiana di Antropologia e di Etnologia.
280 GENOA ...*Museo Civico di Storia Naturale.
281 MILAN ...*Reale Istituto Lombardo di Scienze Lettere ed Arti.
282 „ ...*Società Italiana di Scienze Naturali.
283 MODENA ...*Regia Accademia di Scienze, Lettere ed Arti.
284 NAPLES ...*Società Africana d' Italia.
285 „ ...*Società Reale di Napoli (Accademia delle Scienze Fisiche e Matematiche).
286 „ ...*Statione Zoologica (Dr. Dohrn).
287 PALERMO ...*Reale Accademia Palermitana di Scienze Lettere ed Arti.
288 PISA ... Reale Istituto Tecnico.
289 „ ...*Società Toscana di Scienze Naturali.
290 ROME ...*Accademia Pontificia de Nuovi Lincei.
291 „ ...*Biblioteca e Archivio Tecnico (Ministero dei Lavori Pubblico).
292 „ ...*R. Accademia dei Lincei.
293 „ ...*R. Comitato Geologico d' Italia.
294 „ ...*R. Ufficio Centrale di Meteorologico e di Geodinamico.
295 „ ...*Società Geografica Italiana.
296 SIENA ...*R. Accademia dei Fisiocritici in Siena.
297 TURIN ...*Reale Accademia della Scienze.
298 „ ...*Regio Osservatorio della Regia Università.
299 VENICE ...*Reale Istituto Veneto di Scienze, Lettere ed Arti.

Japan.

300 TOKIO ...*Asiatic Society of Japan (formerly in Yokohama)
301 „ ...*Imperial University.
302 „ ...*Seismological Society of Japan.

Java.

303 BATAVIA ...*K. Natuurkundige Vereeniging in Nederl-Indië

Mexico.

304 MEXICO ...*Sociedad Cientifica "Antonio Alzate."

Netherlands.

305 AMSTERDAM ...*Académie Royale des Sciences.
306 „ ...*Société Royale de Zoologie.
307 HAARLEM... ...*Bibliothèque de Musée Teyler.
308 „ ...*Colonial Museum.
309 „ ...*Société Hollandaise des Sciences.

Norway.

310 BERGEN ...*Museum.
311 CHRISTIANIA ...*Köngelige Norske Fredericks Universitet.
312 „ ...*Videnskabs-Selskabet i Christiania.
313 TROMSO ...*Museum.

Roumania.

314 BUCHAREST ...*Institutul Meteorologic al Roumăniei.

Russia.

315 HELSINGFORS ...*Société des Sciences de Finlande.
316 KIEFF ... ...*Société des Naturalistes.
317 MOSCOW ... ...*Société Impériale des Naturalistes.
318 „ ... ...*Société Impériale des Amis des Sciences Naturelles d' Anthropologie et d' Ethnographie à Moscow (Section d' Anthropologie).
319 ST. PETERSBURG ...*Académie Impériale des Sciences.
320 „ ...*Comité Géologique—Institut des Mines.

Spain.

321 MADRID ... ... Instituto geografico y Estadistico.

Sweden.

322 STOCKHOLM ...*Kongliga Svenska Vetenskaps-Akademien.
323 „ ...*Kongliga Universitetet.
324 UPSALA ... ... Kongliga Vetenskaps Societeten.

Switzerland.

325 BERNE ... ...*Société de Géographie de Berne.
326 GENEVA ... ...*Institut National Genèvois.
327 LAUSANNE ...*Société Vaudoise des Sciences Naturelles.
328 NEUCHATEL ...*Société des Sciences Naturelles de Neuchatel.
329 ZURICH ... ...*Naturforschende Gesellschaft.

United States of America.

330 ALBANY ... ...*New York State Library, Albany.
331 ANNAPOLIS (Md.) *Naval Academy.
332 BALTIMORE ...*Johns Hopkins University.
333 BELOIT (Wis.) ...*Chief Geologist.
334 BERKELEY ...*University of California.
335 BOSTON ... ...*American Academy of Arts and Sciences.
336 „ ... ...*Boston Society of Natural History.
337 „ ... ... State Library of Massachusetts.
338 BROOKVILLE (Ind.)*Brookville Society of Natural History.
339 „ ... Indiana Academy of Science.
340 BUFFALO (Ind.) ...*Buffalo Society of Natural Sciences.
341 CAMBRIDGE (Mass.)*Cambridge Entomological Club.
342 „ ...*Museum of Comparative Zoology at Harvard College.
343 CHICAGO ... ...*Academy of Sciences.
344 „ ... ... American Medical Association—The Newberry Library.
345 CINCINNATI ...*Cincinnati Society of Natural History.
346 COLDWATER ... Michigan Library Association.
347 DAVENPORT (Iowa)*Academy of Natural Sciences.
348 DENVER ... ...*Colorado Scientific Society.
349 FORT MONROE (Va.)*United States Artillery School.
350 HOBOKEN (N.J.) ...*Steven's Institute of Technology.
351 IOWA CITY (Iowa) *Director Iowa Weather Service.
352 JEFFERSON CITY...*Geological Survey of Missouri.
353 MADISON (Wis.)...*Wisconsin Academy of Sciences, Arts and Letters.
354 MINNEAPOLIS ...*Minnesota Academy of Natural Sciences.
355 NEWHAVEN (Conn) *Connecticut Academy of Arts and Sciences.
356 NEW YORK ...*American Chemical Society.
357 „ ...*American Geographical Society.
358 „ ...*American Institute of Mining Engineers.

359	NEW YORK	...*American Museum of Natural History.
360	,,	...*American Society of Civil Engineers.
361	,,	...*Editor *Journal of Comparative Medicine and Veterinary Archives.*
362	,,	...*New York Academy of Sciences.
363	,,	...*New York Microscopical Society.
364	,,	...*School of Mines, Columbia College.
365	PALO ALTO (Cal.)	...*Geological Survey of Arkansas.
366	PHILADELPHIA	...*Academy of Natural Science.
367	,,	...*American Entomological Society.
368	,,	...*American Philosophical Society.
369	,,	...*Franklin Institute.
370	,,	...*Geological Survey of Pennsylvania.
371	,,	...*Wagner Free Institute of Science.
372	,,	...*Zoological Society of Philadelphia.
373	ROCHESTER (N.Y.)	*Geological Society of America.
374	SALEM (Mass.)	...*American Association for Advancement of Science.
375	,,	...*Essex Institute.
376	ST. LOUIS ...	...*Academy of Science.
377	,,	...*Missouri Botanical Garden.
378	SAN FRANCISCO	...*California Academy of Sciences.
379	,,	...*California State Mining Bureau.
380	SCRANTON (Pa.)	...*The Colliery Engineer Co.
381	WASHINGTON	...*Bureau of Education (Department of the Interior).
382	,,	...*Bureau of Ethnology.
383	,,	...*Chief of Engineers (War Department).
384	,,	...*Chief of Ordnance (War Department).
385	,,	...*Department of Agriculture, Library.
386	,,	...*Department of Agriculture, Weather Bureau.
387	,,	...*Director of the Mint (Treasury Department).
388	,,	...*Library (Navy Department).
389	,,	...*National Academy of Sciences.
390	,,	...*Office of Indian Affairs (Department of the Interior).
391	,,	...*Philosophical Society.
392	,,	...*Secretary (Department of the Interior).
393	,,	...*Secretary (Treasury Department).
394	,,	...*Smithsonian Institution.
395	,,	...*Surgeon General (U.S. Army).
396	,,	...*U. S. Coast and Geodetic Survey (Treasury Department).
397	,,	...*U.S. Geological Survey.
398	,,	...*U. S. National Museum (Department of the Interior).
399	,,	... U.S. Patent Office.
400	,,	...*War Department.

Number of Publications sent to Great Britain 83
,, ,, India and the Colonies ... 73
,, ,, America 77
,, ,, Europe 158
,, ,, Asia, Africa, &c. 5
,, ,, Editors of Periodicals ... 4

Total 400

J. H. MAIDEN.....
J. W. GRIMSHAW } Hon. Secretaries.

The Society's House, Sydney, 31st December, 1895.

Sydney:
F. W. White, Printer, 39 Market Street.

1896.